PROCEEDINGS

OF THE

First National Meeting

FOREST PRODUCTS RESEARCH SOCIETY

Research · Development · Production · Utilization

FURNITURE CLUB *of* AMERICA

AMERICAN FURNITURE MART BUILDING

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FOREST PRODUCTS RESEARCH SOCIETY

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FIRST NATIONAL MEETING

Opening Session—1:00 p. m. Friday, October 31

President Fred W. Gottschalk called the session to order in the Library Room of the Furniture Club of America. After a brief message of welcome, he outlined the two-day meeting which appeared in the printed program, as follows:

GENERAL PROGRAM

Friday, October 31st

9:00 a. m. — **Furniture Club Lounge Room**

REGISTRATION

There will be no registration fee for members or non-members. Those who have registered in advance by mail may receive their official badge at the advance registration desk. Meetings, tours and the banquet are open to all registrants. Ladies are invited to participate in any of the sessions and other activities listed on the program.

10:30 a. m. — **Furniture Club Lounge Room**

TOUR OF THE AMERICAN FURNITURE MART

This tour of the world's largest furniture display building will demonstrate how the nation's leading furniture and appliance manufacturers show their latest products and how the building organization is set up to handle thousands of carloads of furniture and appliances for the markets. The trip will leave from the Society registration desk and return there in approximately one hour.

12:00 noon — **Furniture Club Exhibit Room**

TABLE-TOP EXHIBIT OPENED

The table-top exhibits provided by producers of forest products, suppliers of equipment or material used by the forest products industries, consumers of wood, laboratories in the wood field, etc., will be open for the entire period of the meeting. The purpose of the table-top display is to provide information for those concerned with forest products development, production, or utilization.

12:30 p. m. — **Marshall Field and Company Private Dining Room**

LADIES' LUNCHEON AND TOUR

Lunch at Marshall Field & Co. and a conducted tour of the store is a special ladies' program. There will be a $1.00 service charge. Detailed information concerning this event may be obtained at the Society's registration desk; the group will leave at 12:00 noon from the registration desk at the Furniture Club. The trip will terminate before 5:00 p. m.

1:00 p m. — **Furniture Club Library Room**

TECHNICAL SESSION I

3:00 p. m. — **Furniture Club Library Room**

TECHNICAL SESSION II

7:00 p. m. — **Main Dining Room**

EVENING BANQUET

(See Banquet Program for Details)

Tickets for the informal banquet which are issued prior to meeting day, October 31, are $4.00 each; if additional facilities are available, tickets purchased on the day of the banquet will be $5.50 each. Inasmuch as the banquet is on Friday, a selection of a fish or meat entree is available.

Saturday, November 1st

9:00 a. m. — **Furniture Club Library Room**

TECHNICAL SESSION III

11:00 a. m. — **Furniture Club Library Room**

BUSINESS MEETING

(Adjournment about 12:30 p. m.)

Over two hundred people took the 10:30 a. m. tour of the American Furniture Mart Building, a feature contributed by Colonel Lawrence H. Whiting and Mr. Frank S. Whiting, officers of the Mart building. President Gottschalk reported that a total of forty commercial firms, government laboratories, and universities were exhibiting in the Exhibit Room directly opposite the Club (see page -- for details) and that advance registration at that hour exceeded 350. Vice-President George A. Garratt, Chairman of the Program Committee, outlined the three technical sessions at which twenty-six papers were presented, all but two were preprinted for the meeting; because of the limited time available, authors were asked to summarize their presentations in a ten-minute period so that there would be time for free discussion from the floor. President Gottschalk then turned Session I over to Chairman Edward G. Locke, and Recorder Kenneth G. Chesley. Pertinent floor discussion appears at the end of each paper.

TECHNICAL SESSION I

Friday Afternoon, October 31, 1947

General Subject: Chemical Utilization of Wood and Integrated Logging

Chairman: Edward G. Locke, Chemical Engineer, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon *(Northwest Regional Board Member, FPRS)*

Recorder: Kenneth G. Chesley, Director of Research, Crossett Lumber Company, Crossett, Arkansas *(South-Central Regional Board Member, FPRS)*

FOREST PRODUCTS RESEARCH SOCIETY

Whole Wood Fiber Manufacture

C. C. Heritage
Technical Director

and

T. C. Duvall
Manager, Development Department, Wood Conversion Company, Cloquet, Minnesota

Whole wood fiber in the dry form has only recently been commercialized. This paper deals briefly with the various means for resolving whole wood to fibrous form, the present state of the commercialization of these processes, the importance of controlled steaming of the wood prior to fiberizing, the manufa ture of insulating fiber by the Asplund process as an example of whole wood fiber, and the use requirements and physical property values to be met when the fiber is pneumatically placed and felted in the space to be insulated.

Introduction

THE art of reducing wood to fibrous form is old and has been and is practiced largely for the purpose of reassembling the fibers in water suspension into a felted sheet, to form products of varying densities and thicknesses ranging from paper to structural board. Fiber-making processes and the equipment required have been developed primarily for fiber amenable to easy gelatinization, so that the water laid sheet is adequately bonded upon drying. Using fiber as such in the dry form to comprise a structural unit has received little attention, and has been largely confined to adapting fiber manufactured for the water suspension processes without attempting manufacture of fiber developed directly for the use. This paper deals briefly with a small portion of the wood fiber field, that in which the fibers are characterized as consisting substantially of the whole wood by virtue of the absence of chemical action on the wood constituents. Whole wood fibers are increasing in commercial importance and are proving useful in many ways. Attention is called to the various manufacturing processes which may be employed, with particular emphasis upon the merchandizing of whole wood fiber in dry baled form as a new article of commerce and upon one of its uses as a felted-in-place thermal insulation.

Physical Characteristics of Wood Which Make it Useful for Fiber

Wood derives its structural strength principally from the libriform cells in hardwoods and the tracheids in conifers. Libriform cells in hardwoods are short, rarely exceeding 2 mm. in length, whereas the tracheids in conifers normally average approximately 3.5 mm. or longer, depending upon the species. These cells are arranged with their long axes parallel to each other and to the axis of the tree or portion thereof. Composed chemically of cellulose, with some hemicellulose and lignin, and physically of fibrils spirally disposed about the cell axis, these cells are joined by the middle lamella, chiefly lignin and polysaccharides. The structure is thus heterogeneous and anisotropic; the problem in converting wood to whole wood fiber is entirely one of cleaving the structure at the junction between fibers, with as little rupture of the fibers themselves as possible.

Means of Resolving Wood Into its Structural Unit, the Fiber

Reducing wood to its component fibers may be accomplished broadly in two ways:

1. By somewhat selective chemical action, removing the middle lamella to the point where only the fibers remain (chemical pulping), or to a degree whereby a relatively mild mechanical action will part the

cells at the weakened middle lamella (semi-chemical pulping). Fibers so produced have been changed greatly in their individual and their mass physical properties from those they possessed in the original wood structure. They have lost stiffness, resistance to compression, resistance to flexure, resistance to gelatinization, and are no longer highly elastic. The loss of these characteristics reduces their utility for many commercial uses. These fibers are not those of whole wood.

2. Separating the fibers mechanically, in the absence of added chemical, at room or elevated temperatures, in the presence or absence of suspending water. These fibers are in general those of the whole wood. This mechanical pulping is accomplished by the following means:

   a. Direct fiberizing at room temperature, using wood of normal green moisture content.

      The McMillan process, named after the inventor, is an example of this method. Pieces of wood contained in a magazine are reciprocated lengthwise in contact with rapidly rotating brushes, the "bristles" of which are steel pins with points of special design, which, being held out centrifugally, yieldingly comb the wood surface. There is thus produced a fibrous mass of bundles, individual fibers and fragments, with gelatinization absent.

      Many attempts have been made to produce whole wood fiber merely by comminuting green wood to chips or hogged fragments followed by attrition moist or in aqueous suspension. The resulting product is a mass of broken semi-fibrous particles of limited utility. The necessity for softening of the union between fibers thereby becomes apparent. The action required is one of applying heat, steam or chemicals to the comminuted wood.

   b. Comminution, batchwise steaming, and atmospheric attrition of wood in either moist condition or in aqueous suspension.

      The principle of softening the fiber to fiber juncture by the application of moist heat, as with steam, has been known and employed for many years in the steam bending of wood. The early application of this fundamental to the fiberizing of chips involved batchwise steaming in a closed vessel, either with or without liquid water being present, followed by discharge of the vessel contents to an intermediate storage at atmospheric pressure, thence feeding the processed chips to an attrition mill, such as a Bauer. The operating problems involved in tying a batchwise step into a continuous one proved too great to make such a process practical or the product thereof useful. Generally speaking, the steaming conditions were too severe and the softening of the wood was minimized or lost by the time attrition could be carried out, so that weakened fiber fragments tended to predominate in the fiber mass produced. It became evident, as the art developed, that either of two changes would be helpful, namely the steaming should be continuous or the attrition should be performed under the steaming conditions.

   c. Comminution, continuous steaming, and attrition of moist wood in a pressure environment.

      This sequence of unit operations is performed in the Asplund Defibrator, wherein chips are fed continuously by means of a screw into a chamber where retention time and steam pressure are controlled. Still under pressure, the chips move to attrition disks and are there fiberized. The fiber is then immediately discharged with exhaust steam to the atmosphere through appropriate valves. With temperature and retention time under control, optimum conditions are maintained for softening the middle lamella, thus permitting fiberizing with very little fiber breakage. No gelatinization accompanies fiberizing. Electrical energy consumption is low.

d. Comminution, continuous steaming, and attrition of wood in moist condition or in aqueous suspension at atmospheric pressure.

This sequence has received the attention of many inventors, as shown by the prior art, but is only now approaching commercialization through the development of adequate equipment. Typical problems are the independent control of production rate and duration of steaming, and the continuous discharge of the treated chips from the steam pressure environment and their controlled introduction to the attrition step. One form of equipment utilizes screw feeding against steaming pressure, as developed by Asplund, followed by conveying of the chips under pressure through one or more sections of horizontal tubing, thence discharging through a tapered screw to a standard attrition mill at atmospheric pressure. The fiber produced appears to be separated in the main at the middle lamella and some degree of gelatinization is established.

e. Direct fiberizing at elevated temperature in an aqueous environment.

The manufacture of ground-wood or mechanical pulp as practised for many years typifies this method, wherein pieces or bolts of wood are abraded by contact with the surface of a rotating horizontally mounted cylindrical stone roll, carrying a substantial flow of water into the grinding area to obviate excessive temperatures and carry away the fibrous product formed. A considerable portion of the fiberizing is not done at the fiber to fiber juncture and the fiber fragments are rather highly gelatinized.

Either chemical treatment of the wood or steaming with excessive pressure or duration removes wood substance and does not produce whole wood fiber as considered in this paper.

Commercialism of the Mechanical Fiberizing Processes

Manufacture of whole wood fiber has been commercialized to at least some extent by all of the foregoing processes. Of the fibers not subjected to steaming during processing, McMillan fiber has been commercialized to a minor extent. Where a coarse, stiff, bulky, low cost fibrous mass is required, this product is useful. The manufacture of ground-wood pulp is widely commercialized in the manufacture of certain grades of paper. Fiber quality depends largely on operator skill. The process is not capable of close control and is relatively inflexible. Its widespread use results from low manufacturing cost where cheap power is available and its particular adaptability to certain products where high strength is not required.

Processes wherein the wood is steamed prior to fiberizing have been tried by many, but until the last ten years have not been widely commercialized. Combining a batchwise steaming step with a continuous fiberizing step is not conducive to adequate temperature control at the time of fiberizing. Steaming is a critical process step with respect to control of the fiberizing process, fiber yield, and character of the fiber product. Control of the process is dependent on the temperature range from the mere softening of the middle lamella to that point at which the middle lamella becomes highly plastic. In the Asplund process, temperature and duration of presteaming are controlled at a point where the middle lamella is sufficiently softened to permit easy separation of the fibers but below the point where increased temperature and/or retention time will render the middle lamella so plastic as to cause fouling of the fiberizing elements. These optimum conditions vary with wood species, moisture content, and other factors, and are critical.

Fiber yield is affected by formation of water solubles and gasification loss. Both factors are important where aqueous processing is practiced and the latter is important where moist processing is involved. The following table shows the effect of steam pressure and time of exposure imposed on whole fiber from aspen,

Populus tremuloides, with respect to yield of fiber, water solubles, and gas:

Steam Pressure p.s.i.g.	Steaming Duration, minutes	Weight Yields, percent of original wood		
		Fiber	Water Solubles	Gas
50	4	86.8	10.0	3.2
120	4	84.0	13.0	3.0
150	2	85.5	11.3	3.2
150	4	79.9	15.9	4.2
150	6	74.0	23.7	2.3
150	8	60.8	26.8	3.4
200	2	73.3	19.0	7.7
200	4	67.6	16.7	15.7
200	6	57.2	30.0	12.8
200	8	62.5	27.0	10.5

It thus appears that under 200 p.s.i.g. pressure and near 175 p.s.i.g. and at about 2 to 4 minutes steaming duration, the shorter time for the higher pressure, there begins a major increase in the gasification by steam depolymerization of the wood. The point where gasification is substantial varies according to time, temperature, wood species, and other conditions. Nevertheless, for a given set of conditions except temperature, there will be a critical temperature which must not be exceeded if substantial gasification is to be avoided. Also above a point near 200 p.s.i.g. the depolymerization appears to be more complicated than below it, control by time limitation is not effective, and repolymerization probably takes place. In processes where subsequent steps are carried out in water suspension, formation of water solubles as well as gasification is important. Operation at high pressures and short exposure times favors fiber yield over lower pressures and much longer exposure times.

The importance of precise control of the steaming operation over a wide range of conditions cannot be stressed too highly. In the last ten years the Asplund process, which permits such control continuously, has come into widespread use. The fiber may be produced with any degree of depolymerization by addition of auxiliary devices for increasing retention time. Whole wood fiber is produced, however, generally with a retention time of approximately one minute.

Asplund Defibrator Fiber

Whole wood fiber may be defined as individual fibers and fiber bundles composed of substantially all the original wood substance. Asplund fiber is perhaps the most interesting and useful of this type. The unit operations involved in the manufacture of whole wood fiber by the Asplund process, as practiced by Wood Conversion Company, are as follows:

1. *Wood Preparation*

   Jack pine, *Pinus banksiana,* is received in the usual form of round pulp wood. It is chipped to an optimum length of 0.75 in. parallel to the grain. Chips are delivered to a screen, with oversize particles going to a rechipper and thence again to the screen. Accepted chips are conveyed to chip storage.

2. *Chip Conditioning and Fiberizing*

   Chips are delivered from the chip bin by gravity and metered to the Asplund feed screw by means of a weighing feeder. The feed screw delivers the chips continuously, against the operating steam pressure, to the horizontal preheater. From this point to completion of fiberizing, the wood is in direct contact with steam under controlled pressure. Asphalt characterized by a softening point of 170 deg. F., yet tacky at room temperature, is pumped in molten condition into the preheater. The asphalt then becomes intimately mixed with the chips. Displacement by entering chips forces the chips horizontally to the vertical preheater, where they drop by gravity to a short enclosed screw conveyor. The short screw delivers them through an opening in the stationary element of a pair of attrition disks. The rotating element, acting against the stationary one, rubs the chips to fiber, the action being controlled by disk pattern, clearance and spring pressure. The fiberizing action of the disks uniformly distributes the asphalt on the surfaces of the fibers. The fiber is discharged at the periphery and moves with the exhaust steam to the atmosphere, through a pair of reciprocating valves. At a point where the fiber leaves the chamber housing the disks, and ahead of the discharge port, a solution of fire-retarding chemical is pumped in under pressure. The chemical solution is uniformly distributed on the fiber by the turbulence occasioned in the exhausting of fiber and steam to atmosphere. The exhaust steam is then used to convey the

fiber in suspension through an appropriate pipeline to a cyclone collector. The fiber, as delivered, is in a well fluffed condition and contains approximately the same amount of moisture as the original wood.

3. *Fiber Drying*

   The moist fiber directly from the Asplund Defibrator is conveyed on a travelling screen through a tunnel dryer, where air at 250 deg. F. is passed at high velocity through the fiber. The drying operation is completed in four minutes, reducing the fiber moisture content to six percent total basis.

4. *Baling for Shipment*

   The dried fiber then passes to a pair of hydraulic balers. The quantity for each bale is determined by volumetric means in a hopper over each baler. Bales are compressed under a unit pressure of 40 p.s.i. On completion of wire banding the pressure is released, resulting in a uniform bale of ten pounds per cubic foot density. The fiber bales are shipped unwrapped in carload quantities.

The possibility of improved thermal insulation of totally enclosed spaces, such as those found in domestic refrigerators, through felting bulk fiber directly therein attracted the attention of Wood Conversion Company several years ago. A complete analysis of the use requirements, and correlation of fiber properties therewith, led to the selection of the Asplund process and jack pine wood for the manufacture of whole wood fiber for this market. The controlling use requirements are as follows:

1. High thermal resistance of the fiber felt.
2. Felting of the fiber at proper density, with proper degree of resilience of the felt under pneumatic pressures employed during installation without subsequent settling of the felt under conditions of use.
3. Freedom of the fiber from dust, permitting a clean operation during installation.
4. Sufficient toughness of the fiber to prevent degradation of property values during installation.
5. Water resistance of the fiber.
6. Permanence prior to and after installation.
7. Lack of corrosiveness of the fiber felt.
8. Freedom of the fiber from odor; no tainting of food.

The above use requirements correlate with the following properties:

1. Particle size distribution of the fiber, as measured by wet screen analysis.
2. Thermal conductivity of the felt at use density and thickness.
3. Impact resistance of the felt, as measured by final felted density of the impacted fiber mass.
4. Compressive resistance of the fiber mass, as measured by pressure required to compress the fiber mass to a fixed density.

Fig. 1.—Uncompressed fiber mass, 1.3 lb. per cu. ft. density.

Fig. 2.—Fiber mass compressed to 4 lb. per cu. ft. density as obtained during use application.

5. Resilience of the compressed fiber mass, as measured by expansion following compression to a fixed density.
6. Friability of the fiber, as measured by rate of particle size breakdown under mechanical action.
7. Water repellence of the fiber, as measured by water retention following centrifugation of soaked fiber.
8. Mold resistance, as measured by visual rating of aged incubated fiber inoculated by standard test organisms.
9. Fire retardance, as measured by the extent of charred area following application of a standard source of ignition.
10. Corrosion resistance, as measured by weight loss of standard copper and steel sheets exposed to a moist fiber mass.
11. Fiber odor itself and odor and taint of unsalted butter placed in close proximity to the fiber, as measured by judgment ratings.
12 Dust content, as measured by dry screening.

Plant manufacturing control is maintained by testing the product for the values of the major controlling properties, namely, particle size distribution, compressive resistance, resilience, dust content, and fire retardance.

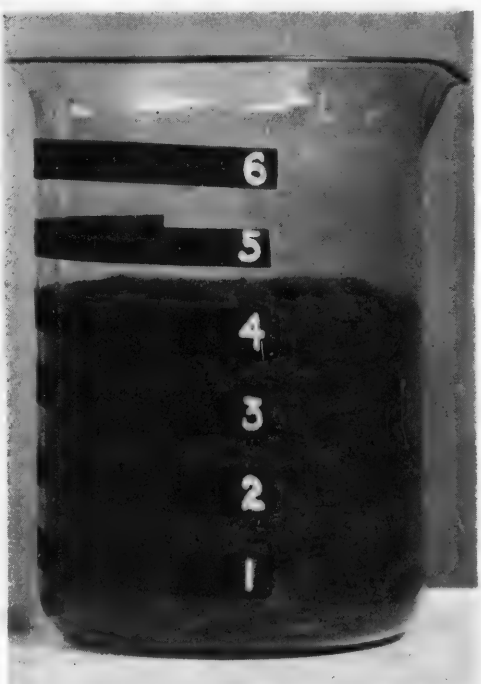

Fig. 3.—Fiber mass sprung back to 2 lb. per cu. ft. density, this property insuring retention of the felted fiber in place during use.

Raw materials used and processing conditions imposed were chosen as follows:

Jack pine wood was selected for the long average length of its tracheids. Asphalt is added to provide water and mold resistance, reduce dustiness, improve felting, and increase toughness. Certain chemicals are added to impart fire retardance without rendering the fiber friable or corrosive.

The Asplund processing conditions were set at 150 p.s.i.g. steam pressure and a retention time of one minute, to provide fiber in high yield and of an optimum particle size distribution, thereby insuring the highest thermal resistance consistent with optimum compressive resistance and resilience (Figs. 1, 2, and 3) of the fiber felt. The processing conditions provide fibers separated at the middle lamella, yet with the intercellular lignin substantially intact on the cell walls, thus contributing stiffness to the fibers and compressive resistance and resilience to the fiber mass. The lignin coating presents a roughened surface, helping to achieve the excellent felting qualities required by the use. Steam depolymerization is not carried far enough to weaken the middle lamella joining the tracheids in the fiber bundles, thus permitting a particle size distribution (Fig. 4) ranging from single cells to fiber bundles up to 20 mm. long which is necessary to obtain high thermal resistance and optimum mass properties.

The Pneumatic Packing Process Using Whole Wood Fiber

The dry fiber is delivered to the customer in compressed bale form. Processing equipment is installed in the customer's plant to transform the baled fiber into a homogeneous felt (Fig. 5) at the proper density in the insulation spaces of the refrigerator. This is accomplished by means of an automatic process integrated in the refrigerator production line. Baled fiber is placed on a belt conveyor, with tie wires and bale ends removed, leading to a rotating toothed drum functioning as a bale breaker. The fluffed fiber is picked up by a high static pressure blower and delivered under pressure to a fixture, which replaces the refrigerator food compartment during the packing process. The carrying air is vented through screens in the fixture, so arranged as to provide uniform density of felt throughout the insulated space, of from 3.5 to 4 lb. per cu. ft.

Fig. 4.—Fractions of Asplund whole wood fiber from jack pine showing range of particle size from large fiber bundles (on 8 mesh) to individual fiber cells (on 80 mesh).

Fig. 5.—Portion of felted fiber mass removed from insulated refrigerator cabinet.

Operation of the process is obtained by moving the cabinet to be insulated, with its open side up, to the pneumatic packing station, where it is stopped over a pneumatic hoist. The operator pushes a button, and the hoist raises the cabinet to a position such that the fixture occupies the space filled by the food compartment in the completed refrigerator. The raised hoist closes a limit switch, which starts the feed conveyor to the shredder and opens a gate in the line between the blower and the fixture. When the insulation space is filled, a cut-off control, activated by sharply changed static pressure conditions in the pneumatic system, stops the fiber feed, closes the blast gate, and lowers the hoist. The food compartment is then inserted in the insulated cabinet, in the space just vacated by the fixture, and the cabinet passes down the line to the next operation. The process is also adapted to insulating the refrigerator doors, using a fixture replacing the interior door panel.

Tests on insulated cabinets show improved thermal performance, due to the thermal conductivity (K factor) of the fiber at use density of .24, and the complete absence of cracks, voids or openings through the insulated space.

Conclusion

That small portion of the total wood fiber field described as whole wood fiber, i.e., wood in fibrous form substantially in its original condition, has been discussed with a brief description of the various processes for the production of whole wood fiber and comments on the extent of the commercial use of each and the utility of the corresponding fiber. Emphasis has been placed on the continuous Asplund process for whole wood fiber, because of the high quality of product and the ease of control and versatility of the process. As an example of the commercialization of a specific use for whole wood fiber, the thermal insulating fiber of Wood Conversion Company has been described, together with the means of felting this material quickly and cheaply directly in the space to be insulated. Whole wood fiber of high quality is a relatively new industrial material, the technology of which has now progressed to the point where specific uses can be met by adequately engineered unit operations, both in manufacture and use.

Discussion

Mr. Armin Elmendorf (The Elmendorf Corporation): The paper presented by Dr. Duvall stresses the various systems for producing whole wood fibers by mechanical means, so that cleavage takes place so far as possible at the junction between the fibers and with as little rupture of the fibers themselves as possible. It dwells on the Asplund technique and includes a table showing the percentage of the original wood which disappears as water solubles or as gas when the chips are subjected to steam pressure ranging from 50 to 200 pounds per square inch. It is significant to note that at the higher steam pressures, from 25 to 30 percent of the wood is lost as a water soluble and that from 10 to 15 percent disappears as a gas, so that the yield may be only about 65 percent. It should also be pointed out that, while a fair percentage of the fibers exist in the form of bundles, most of them are very short and fine and that, when individual fibers are produced, they are inclined to be brittle. Such fibers are very free and permit ready separation of the water on the felting screen, but in the production of an insulating wallboard, greater interlocking is necessary in order to obtain satisfactory strength. The addition of fibers that have been further reduced by beating to produce a fair degree of gelatinization is therefore necessary. It should be noted that gelatinization or fibrillation represents the partial reduction of the ultimate wood fiber obtained in the Asplund process into the component fibrils and that, when fibers are so reduced, their chemical composition has not been materially altered. Beating to produce gelatinization is therefore an important phase of fiber manufacture and, in my opinion, the advantages of adding gelatinized fibers to mechanically whole fibers or fiber bundles for the purpose of bonding is a fertile field for further exploration.

The production of fine, long strands of fiber bundles commonly referred to as wood wool is not commented upon. It would seem that this subject should be given consideration. When wood fibers are combined with binding materials to produce a synthetic board, it is important that long slender fibers be used. The art of manufacturing such fibers has been developed to a high degree in the production of fine excelsior, but other methods of producing somewhat the same results have been recently developed.

Dr. Irving H. Isenberg (The Institute of Paper Chemistry): Mr. Duvall's description of the use of Asplund fiber for insulation has been particularly interesting. Increased research on the Asplund process both here and abroad will undoubtedly increase its future usefulness. While the speaker states that manufacture of ground-wood pulp is not capable of close control, it is apparent that the grinding of the wood is controllable to some degree, in view of the use of the pulp for such diverse products as catalog paper, newsprint, and wallboard.

Mr. Duvall: The ground-wood process, of course, has wide usage. However, the product does vary in individual grinders. When the stone is new the product differs from that produced when the stone is worn down. It is possible, of course, to standardize the product in a plant where several grinders are in use.

Dr. Isenberg: It appears that the Masonite process of exploding fibers after subjection to high steam pressures has been omitted from the list of processes given by the authors. Should this not be considered as a mechanical process?

Mr. Duvall: Yes, the Masonite process is classed as a mechanical process. The defiberizing procedure is carried on batch-wise but under careful control.

FOREST PRODUCTS RESEARCH SOCIETY

Certain Problems in the Field of Lignin Chemistry*

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The author reviews a number of the troubles presently encountered in the field of lignin chemistry, such as:

1. Much of the research which has been carried on in past years is not usable today due to uncertainties with regard to the products studied by these investigators. It is essential that investigators in this field define their materials exactly so that the work can be reproduced. If the methods are not capable of exact reproduction, then some other form of raw material should be selected.

2. Lignin, as it is presently produced in its industrial phase, is a secondary product and more often just a waste material which is considered rather as a disposal headache than an asset. This results in a poor psychology.

3. Lignin chemistry suffers from a lack of interest in fundamental lignin studies by university faculty and graduate students. Whereas in former years there were a number of very eminent professors who were carrying on extensive studies on lignin through their graduate students, currently the number of faculty members working on the subject is few and the graduate students available are also limited in number. The reason in part for this is the fact that funds are not freely available to such laboratories for fundamental work in the field of lignin.

The importance of the better utilization of lignin warrants a group approach, for lignin is a minor responsibility to many groups but the main responsibility of none. Co-ordinated work should be carried out by organic chemists, physical chemists, biochemists, physicists, etc.

While some advances have been made in recent years on the fundamental chemistry of lignin, the principal contributions have been related to applications particularly in the field of tanning and plastics. Interest is now being aroused in lignin as a source for pure organic chemicals. Fundamental work on the oxidation of lignin has developed the esters of vanillic acid as nontoxic food preservatives with wide usefulness.

In conclusion, it should be said that lignin as a raw material for the production of such compounds is still largely in the stage of wishful thinking. It is important not to give any different impression to the public through semi-scientific technical publications. It is nevertheless true that the development of usable products from lignin would permit the expansion of many marginal wood chemical operations on a sound economic basis.

WE HERE are all interested in wood as a raw material for chemical conversion, particularly as we view the increasing scarcities in a number of other raw material fields. The complete utilization of lignin is an important key to the most economical use of wood. I should like to direct my report to some of the problems which need to be recognized before lignin becomes a positive asset on a cost sheet in a wood utilization program.

A vast amount of research time, effort, and money has been spent over the last 50 years in the general field of what might be called "lignin chemistry." Unfortunately, a lot of this work is of doubtful value as a basis for further research, due largely to the lack of definition given by the investigators to their products investigated. Lignin chemistry is probably affected as much by the "science" of semantics as any branch of chemistry. In the first place, we are dealing with a material commonly defined by an analytical method; one whose molecular structure in wood is different than in most of its isolated forms and whose structure in isolated form differs in accordance with the method used in its separation. We are in ignorance as to the origin of lignin in wood and there are even those who would dispute its existence.

When working with such an uncertain material, it becomes extremely important to define the materials and processes exactly or the results of the research cannot be reproduced by later investigators. It is essential that the source of lignin and the methods utilized in isolation and purification be stated rather exactly. In many printed reports on lignin researches, the authors will describe their raw material as sulfite liquor, straw lignin, alkali lignin, or butanol lignin. In the case of sulfite liquor, they do not seem to be aware of the fact that the waste liquor from hardwoods differs from that of softwoods, or that Mit-

* A portion of this report was prepared for the Wood Chemistry Subcommittee of the Food and Agriculture Organization of the United Nations and presented at their recent meeting in Appleton, Wisconsin, September 3, 1947.

scherlich sulfite liquor is different from quick-cook liquor. Old samples of liquor are different from fresh samples.

Lignin research also suffers from the fact that lignin in its industrial phases is a secondary product or even a waste material and is consequently considered more as a disposal headache than as a chemical asset. Thus, the important emphasis is placed on the easiest or cheapest way of disposing of the material in the form represented by the waste. The psychology here is poor, for any process of modification requires low cost and a low selling price for the product by reason of this point of view.

Lignin research of today suffers from a lack of interest in a fundamental study of lignin on the part of the university professors and industrial organizations. The pages of the technical literature of five, ten, and fifteen years ago contained many contributions to lignin chemistry from the laboratories of famous investigators. For example, Freudenberg's series on lignin numbered at least 56 papers, with No. 56 appearing in *Berichte*, October 6, 1943. Hibbert's lignin series that same year listed the 78th paper on lignin. Hägglund likewise published an extensive series over the years. In contrast, the lignin research being done by industry today is set up to meet its immediate requirements, and only a few men are working in university and institute laboratories; reference should be made to the work of Erdtman, Purves, Brauns, Jayme, and Wacek, to list a few, and these are publishing only to a limited degree. The reason for this is, in part, that funds are not freely available to such laboratories for fundamental research in the field of lignin. The major share of the money being spent by industry is being devoted largely to application studies dealing with stream pollution and waste disposal, etc., and fundamental research is included in only a few research budgets. Combining industry and nonindustrial expenditures, pennies are being spent instead of dollars, and even these limited funds are not being used effectively.

If ever a group approach to a research program were warranted, this is the field, for the better utilization of lignin is a matter of current importance to the pulp and paper industry, the lumber industry, and the organic chemical industry, to name just a few, whereas its future utilization will touch the economic well-being of all of us. Lignin is a minor responsibility to many groups but the main responsibility of none. Here is a product continually being replaced by nature and available for use in millions of tons annually. A real program would call for co-ordinated work by organic chemists, physical chemists, biochemists, physicists, specialists in the use of infrared and other analytical tools, botantists, plant physiologists, and wood technologists, to indicate just a few. A program should be set up around some central point and focus in its initial stages on one type of raw material. This would be expensive.

Fundamental research on lignin has made some advances in the last few years, but these need to be expanded. Work being done by Gustavson in Sweden and by investigators in the United States on the function of lignin in tanning is promising. Fundamental work by investigators in Canada has resulted in the development of a lignin plastic operation, which has reached its small-plant stage without running into the usual problems involved in the use of lignin in the plastic field. Fundamental work on the oxidation of lignin has developed as an oxidation product vanillic acid and its esters; the ethyl ester appears to be nontoxic and a food preservative of very wide usefulness. The various esters are also specific fungicides. Other derivatives of vanillic acid have interesting uses in the field of chemical technology.

Lignin as a raw material for the production of a wide variety of organic chemicals is still in the stage of wishful thinking. Unfortunately, there has been too much talk in the public press which would appear to lead the readers to believe that the actual accomplishments have already made lignin as valuable as coal tar. This is the appropriate point to digress and urge greater care in the content and emphasis of stories given the popular press, for too many duds make it very difficult to excite the interest of the public in further work.

There is no question but that the development of usable products from lignin would permit the expansion of marginal wood chemical operations on a sound economical basis. This

can be illustrated by reference to the wood hydrolysis operation at Springfield, Oregon. Right now, the plant is said to operate profitably (although not without some operating headaches) assuming a full operating schedule, but let the price of alcohol drop to its prewar figure or anywhere near its prewar figure, and that process will no longer produce ethyl alcohol on a marginal basis. If the lignin by-product could be sold for 2 cents per pound, f. o. b. the plant, the process would undoubtedly become economically feasible, since there are 10 to 13 pounds of lignin produced per gallon of alcohol.

Modern Techniques For Processing Pine Gum

E. L. Patton

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A modern method for processing pine gum which involves dilution, filtration, washing, separation, and distillation has been generally adopted by the gum naval stores processing industry. The method was developed through fundamental research and pilot-plant work by scientists in the laboratories of the Naval Stores Research Division, New Orleans, Louisiana, and of the Naval Stores Station, Olustee, Florida. Up until about ten years ago, practically all naval stores (turpentine and rosin) were produced in "pot" stills in remote sections of the pine forests of the Southern States. It is estimated that now over 95 percent of all gum naval stores is made by modern methods in the several centralized gum-cleaning plants which have replaced the hundreds of "pot" stills.

BRILLIANTLY clean rosin is now being produced from the "gum," or oleoresin, of southern pine trees. To understand why there was need of a process to produce clean pale gum rosin, a bit of history is necessary.

"Turpentine farming," starting in Nova Scotia in 1606, rapidly moved southward and is now centered in the southeastern United States. The industry has changed its name from "turpentine farming" to "naval stores" and has changed its original purpose from providing pitch and pine tar for caulking ships to supplying turpentine and rosin for everyday use.

"Naval stores" means turpentine and rosin. Rosin is used principally for sizing paper and for making varnish and soap. It is also used in printing ink, linoleum, sealing wax, rubber goods, greases, insulating compounds, and in many other industrial products. Turpentine is used mainly as a thinner for paints and varnishes and in shoe polish. It is used in making synthetic camphor, some synthetic perfumes, and in various chemical and pharmaceutical preparations. Turpentine has a place in the medicine cabinet in almost every home in the land.(1)

The naval stores industry is comprised of "gum" naval stores and "wood" naval stores. Gum naval stores have their source from the living pines—longleaf and slash species. The principal products are refined gum, gum spirits of turpentine, and gum rosin. Wood naval stores comprise (1) destructively distilled processes and (2) steam and solvent processes. They have their source in dead pine wood and stumps (high in resin content) commonly called "lightwood" or "fatwood." The primary products from the first type of process are destructively distilled turpentine, pine oil, pine tar, and charcoal; while from the second type of process come steam-distilled turpentine, pine oil, and wood rosin.

The naval stores industry is of national importance because its products are used in the manufacture of so many articles. It is important to the South because it employs so many people, is an annual crop worth millions, and yields returns from lands that grow pine trees better than other crops.(2)

For generations, the naval stores producer, after collecting his gum, hauled it to a "fire still." Here, over an open fire, the turpentine was vaporized and condensed and the rosin remaining behind in the still was drawn off. This molten rosin was strained through wire screen and cotton batting and run into barrels or drums where it cooled and solidified.

The fire still process, admittedly crude, did not permit washing or filtration of the gum; and if, as often happened, the cups in which the gum was collected were rusty, the rosin was stained and degraded because of the presence of iron. Thus the rosin, although satisfactory for many purposes, had a slightly hazy appearance due to trash which was not removed by the cotton batting. It was obvious that the industry needed a process that would overcome these disadvantages.(3)

The development of such a gum-cleaning process became a major problem at the Naval Stores Station at Olustee, Florida. Experimental work showed that, if the crude gum is melted and at the same time diluted with about one-third its volume of turpentine, it can be both filtered and washed. Filtration first is preferable, either through paper or cloth. This step in the process removes all the fine trash and insoluble impurities. Because of the gummy nature of these impurities, it is advisable to add a small quantity of diatomaceous earth as a filter aid. The diluted and filtered gum is then washed by contacting it with water. It can be readily separated from the water by gravity, as its dilution with turpentine has sufficiently lowered its density. The wash water, containing

certain water-insoluble impurities, is drawn off, together with a small amount of "muck" or agglomeration of water-insoluble impurities and gum. The gum in the "muck" is reclaimed.

All methods of gum cleaning in commercial use involve filtration, but the only process that includes the water-washing step is the one just described, known as the "government" process.[4]

The next step in the government process is to distill the gum, now thoroughly clean. It has been found that distillation with steam is much to be preferred to the fire-still procedure, since steam distillation reduces the fire hazard to a minimum and eliminates the danger of overheating or "scorching" the rosin, thereby darkening it.

The rosin produced by this process is undoubtedly superior to that produced on the conventional fire still.[5] But the process has but little effect on "iron stain"; consequently, to obtain pale rosin from gum that has become contaminated with iron, a further step is necessary.

A treatment of the gum with oxalic acid has been found to be effective in removing iron stain.[6] Brought into intimate contact with the gum, oxalic acid reacts with any iron present to form iron oxalate, which is insoluble and thus removable by filtration and subsequent washing. The preferred procedure is to add the acid while the gum is being melted, the quantity used amounting to only a few ounces per barrel of gum. In the government process, any excess oxalic acid is removed in the water-washing step.

The oxalic acid treatment produces rosin generally from three to five grades lighter than it would be if obtained from the same gum without the treatment. And since the pale grades of rosin usually sell at a higher price than the medium and low grades, it is obviously to the producer's advantage to turn out as much pale rosin as possible.

The use of this treatment for removing iron stain has become common throughout the industry, especially in plants which employ the government gum-cleaning process. The government process in conjunction with the oxalic acid treatment provides a means of producing a rosin best described as "pale in color and brilliantly clean."

Data on cleaned and uncleaned gum, representing the improvements gained by cleaning gum prior to distillation, are as follows:

	Grade	Wastes	Percentage Rosin	Cleanliness as compared to glass—100%
Cleaned gum	WW	0.3	72	96
Uncleaned gum	M	4.3	67	78

Wastes from the cleaning process include chips and filter trash; wastes from uncleaned gum include rosin clinging to chips, fine bark, sand, etc.

Details of a typical plant layout for the government gum-cleaning process are shown on the flow sheet (Figure 1).[7] The processing is accomplished in equipment of simple design, made principally of stainless steel or stainless clad metals. The major pieces of this processing equipment are listed below:

Dump Vats—Open for receiving gum from barrels, which act as storage tanks for the crude gum before it is processed.

Melter — Pressure vessel, steam-jacketed, where the crude gum is diluted with turpentine, mixed, melted, and strained through a coarse screen to remove chips.

Filter—Plate and frame or horizontal enclosed plates, where the smaller particles of trash are eliminated.

Tanks—Jacketed for mixing the hot filtered gum with water for washing. These tanks also serve as storage tanks for the filtered, washed, and settled gum.

The pumps, charge tanks, piping, valves, gages, controllers, thermometers, etc., are standard equipment which has been adapted for use with this processing method. A two-story construction is used to house the entire equipment.

Over a period of years two types of stills have been developed to replace the fire still. One is the batch steam still[8] and the other the continuous steam still (Figure 1).[9] The batch steam still is of conventional design for operation at atmospheric pressures. It usually consists of a cylindrical tank provided with sufficient steam coils for rapid distillation.

The turpentine flows through condensors where it is cooled after condensation. It then passes through automatic "separators," or decanters, where it is separated by gravity from the water, or "low wine." The final traces of

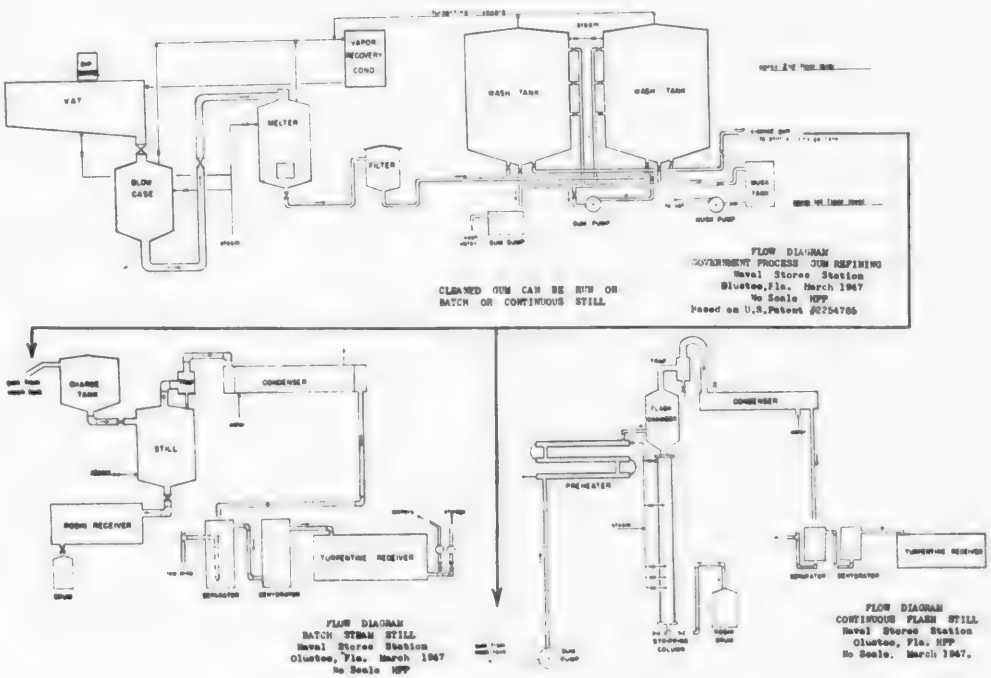
water are removed by passing the turpentine through the dehydrator. The dehydration takes place by passing the turpentine upward through 4-mesh rock salt.[10] The batch steam still equipment has receiving tanks into which the rosin is drawn and packaged. This type of still has a capacity of about four tons of rosin per hour.

The development of a still for the continuous flash distillation of gum has been in progress at the Olustee Station for the past three years. Last season, a small commercial-size still of this type was built and thoroughly tested. This continuous still is non-conventional in design as compared with the batch steam still. It consists of a long vertical pipe on which is mounted a large vessel, called a "flash chamber." The gum, having been cleaned, is pumped through the preheater to raise its temperature. From the preheater, it is sprayed through a nozzle into the flash chamber. About 80 percent of the turpentine is "flashed out" of the gum instantaneously. The turpentine leaves the top of the flash chamber and the rosin continuously flows out of the bottom of the long column. The still operates at atmospheric pressure.

The continuous flash distillation in this type of equipment has several advantages over batch steam distillation. The still is of simple construction, the first cost being less than that of a batch steam still of the same capacity. It uses only half as much steam as an ordinary batch steam still for the same gum throughput. It is labor-saving in operation. It produces a uniform product comparable with that of most of the batch stills.

More and more, the leading producers in the naval stores industry have come to realize the advantages of gum cleaning. The result is that, during the war years when rosin was a critical material, the number of gum-cleaning plants increased phenomenally. In 1940, not more than four plants were in operation, but in 1947 there are more than 30 such plants operating. These plants are distributed throughout the naval stores "belt" in Georgia, Florida, and Alabama. At least two-thirds of the plants use the government process under licenses from the Secretary of Agriculture, while the remainder

Figure 1



use somewhat different processes covered by private patents. The average centralized gum-cleaning plant has a capacity of about two hundred 50-gallon barrels of gum per day or 2400 gallons of turpentine and 30 tons of rosin. The capacity of an average fire still is about 30 barrels of gum per day.

The effect of these central gum-cleaning plants on the overall distribution of rosin grades has been phenomenal. Before 1940, less than one-fifth of the total gum rosin produced was in the three top grades (X, WW, and WG). Now, according to reliable estimates, nearly two-thirds of the total production is in these top grades.

It is believed that, in the near future, practically all of the gum naval stores produced will be made in the central distillation plants and that the fire still will be practically extinct.

The naval stores industry of the future will undoubtedly lean heavily upon chemical research and upon cooperation from consuming industry.[11] In recent years, scientists and engineers have given the industry efficient methods for improving the production and quality of naval stores. The industry has learned to adopt these new methods as rapidly as they are provided. Turpentine and rosin, overwhelmingly the major products of the naval stores producer, have been adapted over a long period of time to manifold uses. Today, the industry is faced increasingly with competition from low-cost products of the petroleum and chemical industries devised through skilled technical research to supply specific needs. Thus, despite the increased efficiency of production and the improved quality of the product, the naval stores industry is threatened with loss of its markets to an aggressive chemical industry. The future growth of the naval stores industry depends on the development, through research, of industrial uses for the components of pine gum oleoresin as individuals, and upon the use of derivatives of the components to meet specific requirements, rather than the adoption of the empiric mixtures, turpentine and rosin, to general consumer needs.

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Discussion

Dr. J. Alfred Hall (Pacific Northwest Forest and Range Experiment Station): I have a considerable personal interest in the matters covered by Mr. Patton's paper, because my acquaintance with the naval stores industry antedates the beginning of centralized distillation and gum refining. As a matter of fact, I believe that the first attempt at washing gum was conducted by George Shingler of the Lake States Station and myself at the little village of Cogdell, Georgia, about 1932 or 1933. I had determined the presence in the gum of certain water-soluble constituents that contributed considerably to the degradation of the color of the resultant rosin. It was later found that these materials also were sensitive to oxidation on the face of the turpentine tree and that the shorter the face the higher the color of the gum.

Aside from all this ancient history, I think the progress made in the southern woods in transforming the production of gum turpentine from a crude, backward industry, in which no substantial progress had been made in 300 years, to a modern one in which technical control of its products is well within the range of our vision, is nothing short of remarkable. And I feel that we should pay a high tribute to the workers who have done so much to bring about this transformation.

Paper and Plastic Overlays for Veneer and Plywood

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Overlays for plywood and veneer are classified according to purpose and characteristics. Plywood overlays are identified as masking, decorative, or structural. Masking overlay papers are used to hide minor defects, such as face checking, patches, and grain pattern, and to produce a uniform paintable surface. This may permit the upgrading of low-grade veneer and thus extend the wood supply. The papers used are thick and of low phenolic-resin content. Decorative overlays are made of high-resin-content papers which are usually prepressed before bonding to wood. The overlay surface is attractive, highly resistant to liquids and abrasion, and requires no finishing or special maintenance. The principal resins used for decorative overlays are phenolic and melamine. Overlays classified as structural are used to impart increased strength, rigidity, water resistance, and wear resistance to plywood. Paper having 30 to 60 percent phenolic resin is self-bonded to wood. The plastic surface is dense, hard, not necessarily smooth, may or may not mask the grain. Overlay papers are also used to make a coverage material from single veneer. Paper thus used imparts considerable strength and stiffness to the veneer. The papers are thick and may contain no resin or as much as 30 percent resin.

THE term overlay, as used in connection with plywood, is an all-inclusive expression intended to designate a multitude of combinations or composites involving wood, but also including paper, metal, plastic, veneer, pulp, or composition materials. Possible combinations of materials and techniques would seem to rival the potential uses in number, and thus far it has been difficult to segregate or classify the basic types according to proper construction or their use. This has been to the detriment of both manufacturer and user. Upon consideration of the well-known properties of a diverse array of sheet materials, it is only normal evolution that composites of the various materials were developed to utilize the singular properties of each to the benefit of the composite. Although the long-practiced art of "veneering" indicates the age of the ideas involved, the relatively recent advent of a large number of resins, adhesives, and plastic materials has given a new stimulus to the possibilities of overlaid plywood. Further recent emphasis resulted from shortages of quality woods and a need for superior products.

This paper is concerned only with overlays of the paper or plastic type, as applied to plywood or veneer. In order to avoid confusion, an attempt has been made to classify plywood overlays into three categories, based chiefly on purpose and characteristics of the completed materials rather than the type of construction, paper, wood, or plastic. Obviously, the dividing lines are somewhat indefinite and the overlap is appreciable, but based on usage up to the present time, certain clear categories exist. Table 1 presents a tabulation of three general classes of overlays for plywood and a discussion of each follows.

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

Overlays for Plywood

Masking Overlays

From the standpoint of the paper manufacturer, plywood producer, and consumer, the masking type of overlay is probably the most promising, or at least worthy of the most emphasis. Two important objectives of this type are: (1) To upgrade low-grade veneer and increase the yield of plywood from a given supply of logs, and (2) to produce plywood with improved surface characteristics. A third objective for future development would be to broaden the base of wood species suitable for plywood. A successful low-cost masking overlay meeting these objectives is likely to be in great demand. Limitations to the widespread use of masking overlays at the present time are economical as well as technical. In the interest of economy and ease of production of overlaid plywood, the use of a single-sheet overlay is indicated. This paper should probably be at least 15 mils in thickness and should contain not more than about 25 percent of phenolic resin. Although the use of low resin

TABLE 1.—OVERLAYS FOR PLYWOOD

Type	Purpose	Characteristics	Remarks
Masking	Mask minor defects, such as face checking, patches, grain pattern. Obtain uniform paintable surface. Permit upgrading of lower grade veneer. Extend wood supply.	Surface of uniform texture. Hardness and paintability at least equal to base wood. May be cut and worked as ordinary plywood.	Overlay paper has resin content of up to 25 percent and a thickness of from 15 to 50 mils. Masking usually achieved by application of one sheet only. Pressure not critical, but same as used for plywood manufacture. Potentially a low-cost utility overlay.
Decorative	Produce attractive and serviceable surfaces.	Surface of attractive color or design and highly resistant to liquids and abrasion. Surface requires no finishing or special maintenance.	Multi-sheet laminates of high-resin-content paper (30 to 70 percent), including a surface sheet of a decorative paper. Laminates usually prepressed and bonded to plywood core.
Structural	Increase strength, rigidity, and wear resistance of plywood. Improve surface of plywood and its resistance to water and water vapor.	Surface dense and hard, not necessarily smooth. May or may not mask grain. Appearance usually not decorative. Composite material strong and stiff. Resistant to water, water vapor, scuffing, and abrasion.	Paper thickness 3 to 10 mils, resin content 30 to 60 percent. Papers may be of high strength. Thickness of overlay from about 0.010 to 0.060 inch. Molding of paper to wood usually done in one operation, and selfbonded to wood at pressures less than the crushing pressure of the base wood.

content is almost mandatory because of its cost, it also is desirable from the standpoint of yielding the proper characteristics. The use of some resin in the paper is believed to be necessary to overcome the severe loss of properties of paper upon saturation with water, although the presence of resin is no particular aid in masking.

From the standpoint of masking typical defects, it is desirable that the resin be cured or nearly cured before application to the paper, as the cured sheet softens less under the heat and pressure of the assembly operations and thus offers the best prospects of "bridging" defects. Because a low-resin-content paper is more closely related in its properties to the base wood than high-density plastics, the problems of face checking, warping, or stress concentrations are likely to be minimized. The completed material may be cut or worked in a manner similar to ordinary plywood. The hardness of the surface should be at least equal to that of the wood. A surface of uniform texture and color is desirable and the paintability must be acceptable for most uses without resorting to special finishing systems. Because of the low resin content, the surface may not be highly water resistant but the paper is strong and scuff resistant when in the wet condition. No great improvement in mechanical properties of plywood of ¼-inch thickness is attributable to the overlay sheet, since the plywood is the controlling factor so far as strength is concerned.

A single type of masking overlay would not represent the optimum for all species of wood, just as the need for overlays varies with the species. For close-grained hardwood the problem of masking is simpler and a thinner and less costly paper may be suitable. Perhaps the most difficult to mask are the softwoods having pronounced summerwood bands, such as rotary cut Douglas-fir, but the challenge is correspondingly greater as the volume production of this species is high and the possible benefits from an overlay are great. A low-cost overlay that is suitable for Douglas-fir may also make possible the use for plywood of certain species of wood that are not used at the present time in appreciable quantities for this product. Possibly examples of such woods may be southern yellow pine and western larch.

The measurement of the masking qualities of overlay papers is difficult, particularly on a laboratory scale. Considerable success was had at the U. S. Forest Products Laboratory by the use of a standard plywood or veneer panel, harboring typical defects both natural and simulated. These defects include holes of various diameters, two types of patches, a knot, cracks of various widths, and wood of both fine texture and coarse texture. Specimens of paper glued to the veneer under standard conditions offered a means of evaluating the comparative masking qualities of various papers under conditions approximating those of commercial practice. The "show-through" of defects through an overlay can be accentuated by viewing a specimen placed at a small angle to a beam of light. In exploratory tests the effect of thickness of paper on the ability to mask was not so pronounced as was expected and it was interesting to note that, although most of the de-

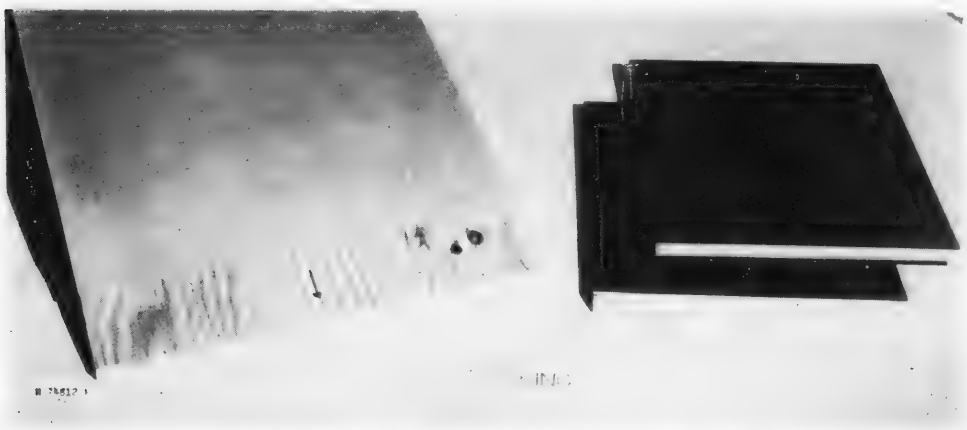

Fig. 1.—*Left,* low-resin-content overlay paper bonded to plywood to mask minor defects and obtain a uniform paintable surface; *right,* samples of final product.

fects were hidden by papers as thin as 0.010 inch, the open splits about 1/8 inch in width were not well masked regardless of the thickness of overlay up to about 35 mils. In many cases the splits were invisible at the time the material was pressed, but following humidification or soaking these defects became visible.

Several aspects relative to the commercial production of overlaid plywood merit consideration. To produce a utility material in the most simple fashion, it would seem attractive to apply a single overlay paper to an assembly of veneers and in one pressing produce a completed overlaid panel. Such a procedure, however, would eliminate the possibilities of sanding to produce panels of uniform thickness. Another method is to produce the plywood in one operation, sand to desired thickness, and apply the overlay in a second pressing. Although the dual operation is more costly, the masking qualities of the paper are less critical since many of the surface defects are minimized by the sanding operation. The thickness lost in the sanding operation is probably equal to the thickness replaced by use of the overlay. In this case of applying overlays to sanded panels, it is probably less critical that the resin in the paper be cured before application to the wood.

At the present time, not much is known about the effect of pulp furnish on the masking qualities of the overlay paper, but kraft and sulfite pulps have been used. The principal resin used is a water-soluble phenolic and saturation is usually done on some type of impregnation machine. To produce large quantities of thick paper at low cost, it would be desirable to incorporate the resin in the process of paper manufacture, either by addition of resin to the beater, to the wet web, or by means of size press equipment. Although saturating the web of paper on the paper machine is feasible, the rapid removal of solvent in drying the paper tends to cause the resin to migrate to the surface and leaves a "starved" interior, resulting in poor distribution of resin and delamination upon soaking. If the machine must be slowed down to overcome this migration, the advantage of machine treatment over a separate impregnation may be lost. Adding resin to the beater offers promise to avoid resin migration, but when making thick papers the slowness of the stock may be increased enough to force a slow down, and good retention and distribution of the resin is often difficult. Perhaps the combination of beater addition and web saturation would be feasible. In spite of the immediate obstacles to the production of a suitable paper in a single operation, the possibility of doing so is nevertheless attractive and promising.

Although the resin content of overlay paper can be low, the total amount of resin in a thick and heavy sheet is appreciable, and this presents one of the economic limitations to its use. It is likely that less costly resin extenders will eventually find use to reduce the require-

ment of phenolic resin. Lignin offers some promise for this purpose and may be made available through the use of high-yield or high-lignin pulps, such as water-cooked woods, or by the actual addition of lignin separated from pulpmill spent liquors. In the molding of a plastic under heat and pressure, a great extension of phenolic resin by lignin can be realized, but the degree of effectiveness of lignin in overlay papers where the pressure used is low is not known at the present. The inherent dark color of the lignin is a disadvantage to its use in overlays, although lignin as it exists in certain high-yield pulps imparts a color to the sheet that is not much darker than ordinary kraft pulp.

Since the strength of paper is not of much importance for a masking sheet for plywood, an opportunity to utilize less desirable species, low-grade woods, or waste woods for pulp may exist. The use of high-yield semichemical pulps is indicated. As an example, a promising experimental base paper has been made from aspen chips that were steamed and refined in an attrition mill and made into a paper of about 0.030 inch thickness on a Fourdrinier machine. The use of less desirable species and a possible outlet for fairly coarse pulps is of interest to paper or pulp mill operators attempting to effect a more complete utilization of their woodlands.

Decorative Overlays

One class of overlays is adequately described as "decorative" and is typified by the familiar plastic table top that enjoys high favor at the present time. The purpose is to produce a highly serviceable and appealing surface of attractive color or design, and toward this goal it has been singularly successful. This type of overlay is made from special papers of high-resin content that are molded into a dense infusible plastic. The problem of producing the overlay paper is probably less concerned with the supporting wood than in the case of the masking overlay. Although the decorative overlay usually masks the base wood, this fact is incidental to the achievement of the chief objectives. One common dependable way to produce decorative panels is to mold assemblies of paper in a hot press between highly polished stainless steel cauls, using pressures and temperatures required to produce a high-quality thin-sheet plastic. A typical assembly of paper for the decorative overlay has its component sheets arranged in the following order: A melamine-impregnated "balancing" sheet, several sheets of phenolic-impregnated "core-stock", a melamine-impregnated "barrier" sheet, a printed paper carrying the design, and a thin transparent high-melamine-content surface sheet. The latter serves to relieve the printed surface of abrasion that would result in wearing away of the pattern or color. Melamine resin is used for saturation of these surface sheets because

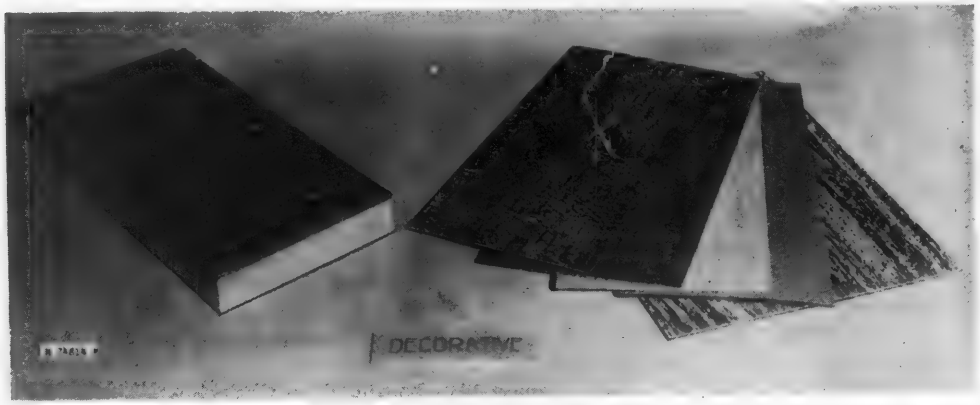

Fig. 3.—*Left,* section from modern table top showing decorative paper overlay bonded to a solid wood core; *right,* multisheet laminates of high-resin-content paper bonded to produce a highly serviceable and attractive surface in a wide range of colors and designs.

of its favorable color, wear resistance, and other characteristics. A thin metal foil is sometimes molded under the decorative sheet to impart "cigarette proofness". In order to minimize warping of the final assembly, another thin panel of phenolic plastic is usually pressed independently for use as a balancing sheet on the opposite side of the wood core. The two sheets of plastic thus produced are bonded in another operation to a core consisting of wood or plywood. By pressing the plastic independently of the wood, it is possible to use higher molding pressures than if molding of paper to wood is done in one operation. One might consider this type of overlay as representing the ultimate for masking of the base wood, but it is interesting to note that "show-through" of the grain of the base wood is often a vexing problem. In the case of using lumber cores, the expansion or contraction of the wood often shifts the overlay in such a manner as to become evident on the plastic surface. Because of the high polish, small surface irregularities that can hardly be detected by measuring are clearly visible. This can be overcome to a great extent by cross-banding the lumber with a veneer on each side. The problem is simpler for plywood cores, although even here there is a certain minimum thickness of overlay that is required to mask the grain of the wood. It is probably desirable to bond the overlay to the wood, using the lowest possible pressure consistent with good bonding. This minimizes the difficulties due to nonuniform expansion of the springwood and summerwood following compression in the press. The advantages of premolding the plastic include flexibility of operations and adaptability to special patterns and constructions. Since the appearance of the surface is of extreme importance for light-colored surfaces, it is advantageous that the thin laminates be molded under dirt-free conditions before being brought in contact with the wood or plywood operations. Limitations include high cost of manufacture and multiplicity of steps in converting resin paper and wood to composite materials.

The simultaneous bonding of overlay papers to wood for decorative purposes is also possible. In this case the papers must be so formulated that molding and bonding to wood can be achieved at pressures less than the crushing load of the wood. Requirements for paper of this type are therefore critical. Since the plastic surface is quite impervious to vapor, the moisture content of wood and the technique of molding are also critical if checking or blistering of the face is to be avoided. One advantage to this type of overlay is in reduction of cost due to a single pressing operation, and it is therefore well suited to the large-scale production of a single-colored overlay, usually of a dark shade. If light-colored overlays are made, it may be difficult to maintain a standard of cleanliness in the plywood operation that is compatible with the requirements of the overlays.

High-resin-content papers that can be molded to make a plastic of high transparency may also be used to produce a decorative surface by enhancing the grain of the wood to which it is molded. Papers for this purpose obviously must be free of dirt and moldable at pressures low enough for molding to wood. The base wood must be sound, of high quality, and of uniform thickness to insure a uniform transparency of the plastic film. Overlays composed of from one to three sheets of paper, which laminate to a thickness of less than 0.010 inch, are used for this purpose. It is possible to obtain a high degree of water and scuff resistance, although films of this thickness are apt to be brittle and fading of color is likely if phenolic resins are used as saturants in the paper. This is a special rather than a general type of decorative overlay and it is probably best adapted to hardwoods or close-grained woods.

The recent advent of "contact pressure" resins has opened a new and interesting field for decorative overlays. The low pressures required for producing paper laminates using these resins make feasible the use of machines for the continuous impregnation and molding of plastic for use as overlays. Several rolls of paper may be simultaneously unwound, passed through resin impregnators, and led through special laminating machines which bond the sheets together and effect cure of the resin. One sheet only of this assembly contains the special color or decorative pattern. Thick and absorbent papers are indicated for this type of plastic, although the paper requirements may vary greatly depending on the resin and process

used. The thin laminate thus produced is subsequently bonded to wood or plywood. These resins are characterized by clear, light colors and good wear-resistant properties.

Structural Overlays

The structural group of overlays includes a series of constructions that fulfill numerous special requirements other than the two already discussed. Although the overlay in this group may be masking or in a certain measure decorative, the basic purpose is different and relates chiefly to physical and mechanical characteristics.

One type, which is well classified as structural, involves the use of a substantial thickness of a high-strength paper that, when molded to the surface of wood or plywood, yields a so-called "sandwich" structure in which the plastic imparts great stiffness and strength to the composite material. Some materials of this type have been used for such applications as flooring for air cargo planes or glider floors, where a high degree of stiffness per unit of weight is required. For this purpose the use of a phenolic-resin-impregnated paper of high strength and density is indicated. This paper is selfbonding to the wood and should be moldable to approximate full density at pressures less than the crushing load of the wood. The resin content of this paper should be relatively low as the fiber is the greater strength-giving component to the plastic. A thin, high-resin paper may be used at the wood-plastic interface to improve bonding, as a good bond is important. By the use of roughened cauls or other means, a pattern may be imparted to the surface to produce a nonskid wearing surface. Because of the thickness and density of this surface, good water and vapor resistance are associated with this type of overlay. The overlay is paintable, but certain modification in the paint formulation may be necessary. The thickness of overlay for most applications of this type is from $\frac{1}{32}$ to $\frac{1}{16}$ inch for a core of less than $\frac{3}{4}$ inch thickness. The potentialities of this type of overlay have probably not been fully exploited and may find additional application in the field of transportation.

In order to impart a high degree of water, water-vapor, and scuff resistance to plywood, the use of thin and dense overlays is effective. An overlay having a thickness of 0.010 inch or less, molded of from one to three sheets of paper of 35 to 50 percent resin content, can greatly reduce the water permeability of plywood and improve its resistance to checking, stain, and chemicals. The smoothness of the surface may be varied according to the surface of the caul used in pressing. The sheets are selfbonding and may be applied to the veneer assembly to permit one-step pressing of overlay veneer. Careful control of wood moisture content, uniformity of wood thickness, and sound base veneers are important for producing

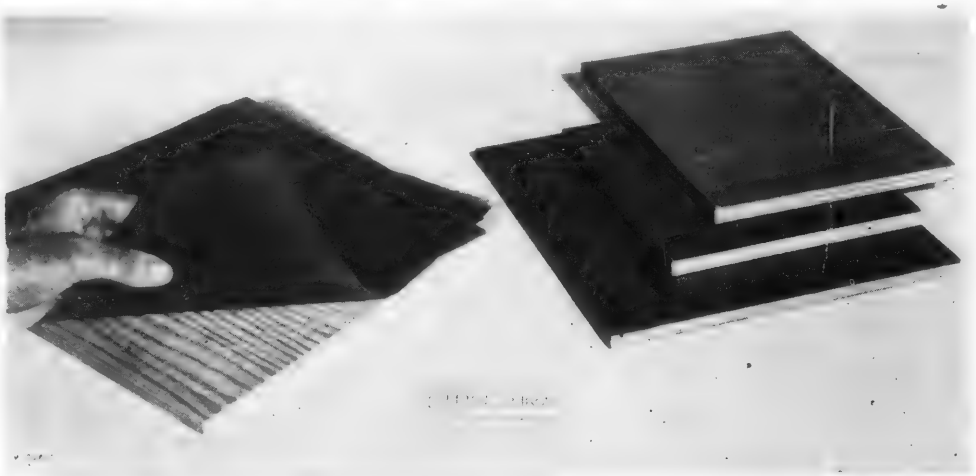

Fig. 2.—*Left,* sheets of high-strength, high-resin-content paper before bonding to plywood to increase strength, rigidity, and wear-resistance of plywood; *right,* samples of final product.

panels free of blemishes. Defects in the form of checks, blisters, or unmolded spots may result if the moisture content, uniformity of thickness, and quality of wood are not carefully controlled. Although certain simple defects of the base wood may be minimized by the overlay, this type of application is not considered to be one of masking. It is usually desirable to paint this type of overlay, although a proper paint is required to obtain good adhesion of paint to plastic.

The potential uses for this type of overlay are indicated by its characteristics of water, chemical, and scuff resistance, but examples may include concrete forms, farm buildings, railroad cars, and luggage or trunks.

Overlays for Veneer

Single veneers with paper overlays may be produced for a great variety of purposes and over a wide range of quality. The use of this material whenever possible is attractive from the standpoint of good utilization, because it permits the manufacture of a greater area of useful coverage material from a given supply of veneer and serves as an outlet for much low-quality veneer.

The range of papers suitable for this type of overlay is similar to that discussed under masking overlays, except that strength of paper is probably more important and resin content less important than required for masking overlays for plywood (table 2). In contrast to the effect of an overlay on plywood, the use of a strong and thick paper on single veneer contributes greatly to the strength, stiffness, and stability of the composite and thus papers should be designed to favor these effects.

Perhaps the highest quality (and most expensive) utility type of overlaid veneer is that produced from a thick and strong paper containing about 25 percent of a water-soluble phenolic resin and bonded to both sides of a sound veneer of 1/10 inch or more in thickness. Minor defects in the veneer may be masked to yield a paintable surface of uniform texture and a composition product of surprising strength and stiffness. The presence of the phenolic resin serves to wet strengthen the paper to such a degree that less than 20 percent of the stiffness of the material is lost upon long-time soaking in water. It is interesting to note that, by the selection of a paper of proper stiffness and strength, it is readily possible to achieve a balanced construction as far as stiffness is concerned. For example, at the Forest Products Laboratory a 1/8 inch Douglas-fir veneer, covered on each side with two sheets of 14 mil kraft paper, yielded a panel of approximately equal stiffness with and across the grain of the veneer.

For applications where strength and dimensional stability are important considerations, it is desirable that the grain direction of the paper and the veneer be at right angles, since the paper is the controlling factor in some of the important properties of the completed panel. By obtaining stress-strain data on the cured overlay papers alone and analyzing the wood and paper composite material as a sandwich construction, it is possible to compute in advance with reasonable accuracy the strength and stiffness that would result from the use of a given paper and veneer. Such an analysis demonstrates the advantage of high strength and grain direction in the paper and the gain due to cross-banding of the veneer and wood. Thus it is possible and feasible to design a veneer overlay to the requirements of use.

The tendency of veneer to expand in the cross-grain direction of the wood due to increased moisture content is greatly restrained by the use of an overlay. For example, an overlaid Douglas-fir veneer with paper (25 percent resin content) and wood grain perpendicular expanded only about one-third as much in the cross-grain direction of the veneer as a like veneer without an overlay. Greater expansion

TABLE 2.—OVERLAYS FOR VENEER

Type	Purpose	Characteristics	Remarks
General purpose	Make usable coverage material from single veneer. Mask simple defects in veneer. Impart strength and rigidity to veneer. Make improved veneer.	Surface of uniform texture, paintable. Composite material is stiff and rigid. Greater dimensional stability than veneer.	Papers are thick (10 to 30 mils), may contain no resin or as much as 30 percent resin. One sheet of paper is applied to each side of veneer, preferably with grain of paper at right angles to grain of veneer. May be used for many uses in place of plywood, but is not directly a plywood substitute.

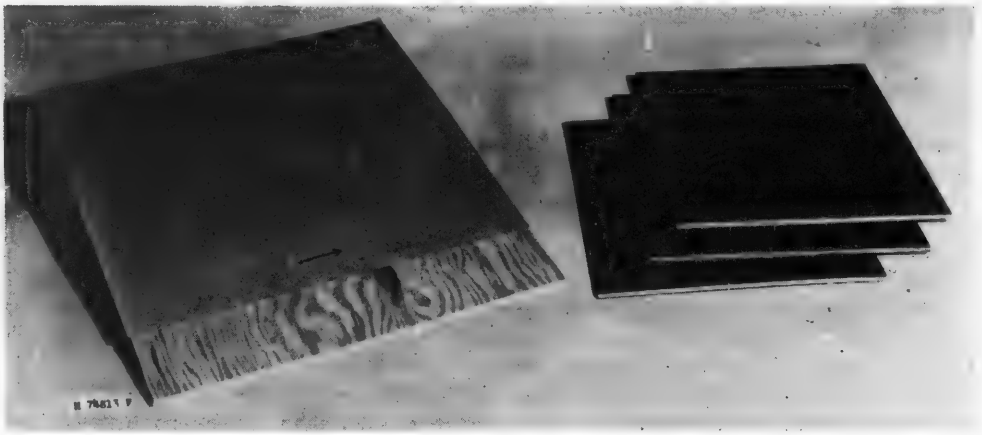

Fig. 4.—*Left,* paper overlay of low-resin-content bonded to a single sheet of veneer to mask minor defects and impart strength, stiffness, and stability to the veneer; arrows indicate grain of veneer and machine direction of paper. *Right,* samples of overlaid veneers.

resulted when the paper and wood grains were parallel, showing that the procedure of crossbanding is again advantageous to obtain maximum dimensional stability. Although the stability of veneer is greatly improved by the overlay, it should be recognized that an overlaid veneer is probably less stable in the crossgrain direction of the veneer than plywood in either principal direction. Since paper expands in both directions and veneer expands chiefly in only one direction, it is perhaps reasonable to assume that no combination of low-resin-content paper and a single veneer can yield a composite as dimensionally stable as plywood. It is important to remember that, although overlaid veneer may be used for many applications in place of plywood, it is not directly a plywood substitute.

For many purposes not requiring maximum abrasion and water resistance, the resin content of paper may be lowered in the interest of economy; for a multitude of uses no resin at all is acceptable. From a consideration of strength when wet, the optimum resin content may be well below 25 percent, but the need for abrasion resistance in the wet condition may dictate a higher resin content. A great improvement in the wet properties of the overlay may be obtained by the use of small percentages of resin.

Ordinary heavy kraft papers glued to low-grade veneers provide useful materials, typical uses for which are toys, furniture, or containers for air shipment. Small pieces of veneer may be pieced together and the gaps "bridged" by the overlay to produce an inexpensive material. It is desirable that the veneer be of a uniform low moisture content, but it is possible to glue the paper to wet veneer. The overlaid veneer may be produced in a continuous machine if desired. It can be scored or formed much as fiber boards for fabricating. For special purposes, the overlay material may be applied to one side only of veneer or strips of veneer, in which case it is possible to roll the product for shipment and use.

General

The foregoing discussion of overlaid plywood and veneer must of necessity be general to include descriptions of many composite materials which are within the scope of this development. It is likely that further experimentation, new materials, and increased knowledge will lead this development to the threshold of much larger production and will become a substantial outlet for resin papers. Because successful development requires the cooperative efforts of the plywood, paper, and chemical industries, an opportunity is presented for a more complete integration of the products and facilities of each for the achievement of a common goal.

Discussion

Mr. Charles B. Hemming (United States Plywood Corporation): In my opinion Mr. Seidl's talk is the best organized of all those I have heard or read on this highly confused and disorganized subject. However, I think he has "pulled his punches" a little bit and I wish to comment on a few aspects of the problem of overlays. First, there is the general problem of reducing conversion costs. There is both a challenge and an opportunity. It just does not make sense to make the paper for the overlay in one plant, ship it to another to be saturated or otherwise treated, and then send it to the panel maker or plywood manufacturer, probably for attachment to plywood which has already been through one pressing operation. To make matters worse, there may even be an intermediate laminator between the paper convertor and the man who attaches the sheet to the panel. This complicated procedure must be eliminated and unrealistic conversion pricing must go, if overlays are to come into their own.

In the field of masking overlays, specifically, it is my opinion that beater addition resins, with all of their problems, are the best hope of simultaneously solving the problems of economics and quality. There is a fundamental reason for this. Such resins are of necessity high in intrinsic viscosity. Their molecular size is so large that they are not wasted by penetration into the fibers, but can be made to lay out on the surface as a very thin film of binder. This gives maximum effectiveness, preserving the opacity and natural masking effect of the fiber. In this connection, Mr. Seidl neglected to point out the marked quality advantage of alcohol-soluble resins over water-soluble resins in a masking sheet. It is recognized that the alcohol-soluble resins are uneconomical, but they serve to prove the contention that their higher molecular weight and refusal to wet and penetrate the paper is the condition we must achieve.

In the decorative overlay field, there is another problem involving dirt and caul maintenance. Plywood plants have been called dirty. I think the modern plywood plant is a lot cleaner than many plants I have seen, but it still is not clean enough for making decorative overlays by present methods. Until we discover a method of procedure that will permit day in and day out production of speck- and spot-free panels in full size in ordinary plywood plants, we will not be able to enjoy a good market and will not have accomplished a single thing that the high pressure laminators have not been doing for years and doing very well indeed. In fact, we no longer even have much of a size advantage over them.

Mr. Armin Elmendorf (The Elmendorf Corporation): Those of us who have been active in the development of overlays for plywood and veneer are confronted with two problems that, in the opinion of the writer, are not sufficiently stressed in Mr. Seidl's paper:

(a) Overlays for masking purposes are particularly important in conjunction with the manufacture of softwood plywood, such as Douglas fir plywood, in which there is a striking difference in density between the springwood and summerwood. Here the problem is primarily that of leveling up the surface to conceal the annual ring structure and only secondarily that of concealing defects such as sound knots. The question that must be answered by the manufacturer is whether a particular thickness of overlay is sufficient to produce the desired smooth surface and at the same time prevent checking of the face veneers. Mr. Seidl mentions that the paper thickness should be at least 15 mils and that the paper should contain not more than about 25 percent of phenolic resin. It should be pointed out that such an overlay costs at least two cents per square foot for each surface. In other words, it doubles the manufacturing cost of ¼-inch plywood. It would seem that, by a partial impregnation of the face veneer, the thickness of the facing might be reduced. Considerable experimental work is now under way to reduce the cost of overlays by reducing the thickness. Until it is demonstrated that this can be done safely and a sound specification can be set up for doing it, the cost of plywood finished with overlays is going to be so much greater than the conventional plywood as now manufactured that its uses will continue to be very restricted.

(b) Thin plastic overlays generally involve the use of urea or phenolic resins. It should be noted that thin papers impregnated with these

resins and then cured under pressure are extremely brittle and that, when single-ply veneers are faced with them, the brittleness of the facing is a distinct liability. Here again, the manufacturer is faced with the dilemma that, if he increases the thickness to the point where danger from cracking of the surface is reduced, the cost becomes a serious liability. Unless the cost of single-ply veneers faced with overlays can be materially reduced, they cannot compete to any great extent with the synthetic lignocellulose hardboards made without resin binders.

Mr. John D. Ritchie (Douglas Fir Plywood Association): The Douglas Fir Plywood Association Testing Laboratory has found that the so-called "high-resin" abrasion-resistant overlay and the low-resin masking sheet can both be painted without particular difficulty. On the low-resin sheet, which is quite porous, we have had the best success with a bodied oil primer which will dry without too much penetration into the surface. Two years' outdoor exposure of conventional exterior paints over these surfaces have indicated very satisfactory results.

Mr. Norman G. Bull (Kimberly–Clark Corporation): I should like to confirm the statement that, in painting a low-resin-content grade of paper overlay, a hard-bodied paint or varnish is desirable. We have had some of these products on test fences for three years and they are still in excellent condition.

Integrated Utilization—Research Task

J. A. Hall

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THE term "integrated utilization" may become corrupted so as to mean whatever it may be desired to mean. This has already happened to such forestry slogans as "selective cutting," "sustained yield," and others. So, I wish to define as carefully as I can the conception of "integrated utilization" to be developed in this paper.

In the broad aspect, integrated utilization in forestry means that the forest crop is harvested and used as it is grown. Since the concept of forest growth involves both quantity and kind of wood, it is clear that integration must gear two things closely: (1) The utilization enterprises must correspond in wood-consuming capacity to the yield capacity of the forests from which they draw their supplies of raw material; (2) they must be able to process in a balanced manner the species and qualities of wood that comprise the yield. The second proposition is the antithesis of one product forestry and requires diversification of the industrial layout. The first proposition is basic but, in most American forest regions, in a state of transition. It is in this zone that the close relationships between forest management and utilization become dramatically clear and important. These relationships are of paramount importance, especially to technicians responsible for planning utilization enterprises.

In planning diversified utilization facilities that are properly adjusted to the yield capacities of tributary lands, there is rarely in forestry the certainty that can obtain, for example, in planning just a sawmill. In the latter case, the daily capacity is fixed; if the mill is geared to a stand of timber, the volume available is known, and the species to be cut and processed determined. The life of the mill may be fairly accurately projected and provision made for orderly liquidation of the investment. But in the former case, where permanence is an objective, the fundamental fact to consider is, "What will the yield be like during the next cutting cycle or even the next rotation?" For the kind of balanced utilization envisaged under integration can hardly avoid exerting a considerable influence on the species composition and quality of the timber stand upon which it depends.

For example, in considerable portions of the Douglas-fir region, practically pure stands of Douglas-fir seem to be the result of old fires. Under good protection and orderly harvest, it seems quite likely that the composition of subsequent crops will contain larger proportions of the more tolerant species. Hence, plans for the future should provide for utilization of these woods.

In the Ozarks, a large proportion of the area is in possession of defective red, black, and scarlet oak. Yet, if that stand can be removed, mixtures containing good white oak and shortleaf can be grown. Management and utilization plans for the future should take cognizance of that fact.

In brief, in many of our forests, a proper application of integrated utilization must be based upon sound understanding of the influence of cutting on the forest itself. The harvest and its character have much to do with the nature of the succeeding crop. It makes no difference whether we are dealing with individual tree selection in hardwoods or area selection in Douglas-fir; the harvest will probably alter the stand composition in some direction. The first task of research, then, is to establish silvicultural principles that answer this question: "What will happen in this stand under this or that or the other cutting method?"

Note that, at this point, economics has not a thing to do with the matter. Only strictly biological principles are evolved—matters of light and shade, soil temperatures and surface temperatures, soil moisture and drainage, repro-

duction mechanisms, etc. We want to know how and why things happen in a stand and what the silvicultural effects of cutting methods may be.

But economics does dictate the choice of cutting method to a large degree, and it in turn is greatly influenced by transportation facilities and the utilization set-up. Since these are most often functions of terrain, location, and markets, and these are widely variable, it becomes clear that basic silvicultural research must cover a multitude of widely varied cutting methods.

The dollar sign enters forcibly into the choice of cutting method, a management choice, but the interpretation of the silvicultural results must be based largely upon purely biological information. The choice of cutting method by management must be based on known harvesting costs which are made up of numerous elements; on transportation costs that are functions of terrain and distance; and on utilization facilities that are determined on the one hand by the matters just mentioned and, on the other, by markets.

None of these divisions of activity is independent; all are closely interdependent. The kind and quality of wood available, the distance to market, and the costs of roads, will go far to determine the nature of the utilization. The kind of facilities to be provided must be guided by the market. Since the nature of the raw material itself is going to shift, and since markets are continually changing according to economic and technological variations, it follows that a completely integrated utilization development cannot be a static affair. It should insofar as possible provide flexibility and possibility of adaptation to conditions that may change rather rapidly.

This interdependence of factors in integration is perhaps most apparent in the consideration of the influence exerted by the harvesting and transportation mechanisms. It must be remembered that the costs of log making and transportation are large elements of total cost, variable within broad limits even within a forest type because of wide variations in stand conditions, road building costs, and distances from primary markets. The tendency in this country is strongly in the direction of mechanization, the substitution of machine capital and maintenance costs for labor costs. This tendency, we believe, makes for higher wages, higher standards of living, and more efficient all-round operation. Yet there is a danger. The fagot-picking Frenchman can do a far better job of close utilization of the forest crop than can a tractor-arch show. We are not fagot pickers for two principal reasons: We are, so far, in possession of enough wood for our normal needs without such close scavenging, and fagot picking or recovery of very small and low-grade wood simply does not pay what we call living wages.

However, large machinery and few men do not usually effect a close job of harvesting the cut. Too often the margin of profit is so narrow that a slight shift in markets forces the leaving of too much wood in the forest. For example, it has been estimated that the drop in lumber prices in the early summer of 1947 and the virtual disappearance of a market for #4 Common Douglas-fir immediately forced most operators to leave from 10 to 15 percent of the cut in the woods. This occurred almost invariably where the outlet was exclusively lumber, and, of course, that is the general condition in Douglas-fir.

It is clear that two sets of conditions can operate to make the harvesting and transportation of such low-grade wood a profitable and, therefore, possible matter. They are: (1) Lower costs of harvesting and transportation, and (2) more values in manufacture.

In considering the broad field of harvesting and transportation, few generalizations are possible. We are dealing with material varying in size from the small pulp sticks of the Lake States and New England to the gigantic redwood and Douglas-fir of the virgin forests of the West. We are dealing in values ranging from poor fuel wood to the finest peelers. The objective of the harvest is uniform; namely, as nearly complete removal of the wood as is feasible. We are witnessing the development of mechanization in the South, dictated in large part by rising labor costs, and, by contrast, the revival of horse logging in the highly mechanized Northwest, dictated by silvicultural necessities in thinning dense stands and salvaging small material after primary logging.

Here are a few of the questions that arise.

What are the costs of growing timber and how should those costs be allocated to the spe-

cies, sizes, and qualities that comprise the harvest? Clearly, management will strive usually for as much of the more valuable material as can be obtained, but there will always be a large volume of material of low value. Part of the high value of quality stuff can often be ascribed to the presence in the stand of low-value trees. Part of the cost of growing mature trees of high value can be defrayed by the earlier harvest of younger, cheaper material. There are some nice jobs here for those who wish to spend effort in cost calculation and economic considerations.

The production of the new crop and the speeding up of the rotation can evidently be forwarded by a good job of harvesting. Fire protection costs can often be lowered in the same way. Are the added costs of clean harvesting to be borne by the current harvest entirely, or shall they be allocated partially to the subsequent crop? Proper distribution of harvesting costs as between grades of material is a complicated matter.

In an integrated business, such questions are bound to be of importance, because the cost of raw material at the processing plant is a vital factor connected with the choice of product to be manufactured. Therefore, economies in growing, harvesting, and transportation of timber are important.

The saw and the ax remain the chief tools of the harvest, but the saw especially bears faint resemblance today to its ancestors. Now we are seeing light, efficient, fast, and portable power felling and bucking saws. We even have a fast, very light, electrically driven limbing saw. We have light, fast tractors for yarding small stuff and huge ones for handling big logs. But the essentials remain the same: We must cut a tree, allow it to fall, often destructively, cut it in pieces, and collect and transport the pieces by some means. The whole business is really pretty crude and costly, both in terms of actual cost of the current operation, and in terms of forest damage and waste incurred. Currently, an enormous amount of thought is being given by industry to better use of the tools it has, and to the development of new tools. The technologist needs to keep acquainted with this field because developments here will have much to do with the cost of raw material at the manufacturing plant.

Similarly, there is heavy ferment in the field of transportation. As cutting gets into the back country where road building is a must, and expensive, men are giving thought to other means of moving wood than by rail or truck. Can logs be economically moved in rugged terrain by overhead cableways? Can cull logs be partially processed to cants in the woods and the good cants transported? Can wood for fiber or chemical processing be chipped or hogged in the woods and transported more cheaply than in log form? These are only a few of the questions with which men are trying to find better and cheaper ways of hauling crude wood from forest to plant.

For, remember, completely integrated utilization usually demands a sustained supply of raw material from a large area. Capital investments are high. Where a small sawmill can and often does live on the product from only a township, a fully integrated layout may require the sustained yield from many times this area. This means distance, and distance means costs. High costs of transportation may effectively bar from use the very low grades of wood whose utilization is most desired from the standpoint of good forestry. Therefore, the utilization man must be very much interested in transportation and its costs.

What is the organizational nature of the manufacturing plants that may comprise a layout for well-integrated utilization. This may be any one of several forms.

First, there is the situation in which land, timber, transport, and factories are all in the same ownership. Clearly such a spread is going to be large both in volume of timber for sustained harvest and in capital invested in factories. This arises quite simply from the fact that there are minimum economic sizes for some kinds of factories that are meshed into the operation, and these will determine the size of the whole. Yet, it is dangerous to generalize even here. There are examples of excellent businesses manufacturing fiberboard from formerly waste wood, in which capacity and capital investment are quite small in comparison, for example, with those required in a chemical pulp mill. Likewise, there are excellent examples of close utilization of low-grade lumber in the manufacture of softwood cut stock and hardwood dimension stock that are

of no greater size than could be conveniently coupled with a medium-sized sawmill.

In a second category there is the situation in which one or more large timber owners do not operate utilization enterprises, these being in separate ownership. Unless satisfactory long-term arrangements are made, it is not likely that utilization facilities developed on the basis of such forest ownership can be sufficiently diversified or integrated. This is because men will not make long-term commitments of capital unless assured of a continuous supply of raw material. The cooperative sustained-yield program of the Forest Service constitutes an attempt to provide the continuity of supply upon which well-integrated utilization can be based.

A third situation exists in which many small forest ownerships are to be tied in with individual, separately owned utilization facilities. Numerous examples can be found of communities that exist industrially very much on a wood base, made up of small enterprises, pretty well integrated, and dependent upon good forest practices in the surrounding small ownerships. But the sum total of such examples is very small when compared with the need for them that exists.

Good examples of the first type of organization are Weyerhaeuser at Longview, Wash., and the Crossett layout in Arkansas. Others are in the process of development.

The second type is exemplified at Shelton, Wash., where the pulp mill of Rayonier is integrated with the large forestry and manufacturing operations of the Simpson Logging Co. All around Puget Sound are other examples, supplied largely by log-trading procedures that are practicable under the easy water transportation facilities of that region.

Many communities in all timber regions are at least partially developed examples of the third category.

One can see no real obstacle in the long run to the expansion of the general idea of integration to a considerable degree.

A major lack in obtaining such expansion lies in the dearth of processes adaptable to relatively small enterprises working on low-grade wood. There are plenty of ways of using good wood, many of them extremely important to a community because of the heavy labor input per volume of wood consumed. But when it comes to using the often enormous volumes of low-grade material available, there is serious lack of suitable processes.

Indeed, from the point of view of good forestry and the kind of utilization being discussed here, one may say, too, that there is serious lack of large-scale processes adapted to low-grade wood. Thus far, the processes best adapted to mass consumption of the huge quantities of industrial and forest waste with which we are confronted are the pulping and crude fiber processes. Yet, there are definite species preferences and, certainly, quality preferences in fiber production that operate against the complete "scavenger" type of mass utilization that is needed.

Technically, the wood distillation industry illustrates the need. Technically, this industry can take almost any kind of wood and produce usable goods. Economically, it can do no such thing.

What is needed is an industry that fulfills the following requirements:

(1) It must operate on any quality of wood.
(2) It should be adaptable to large and small operating units.
(3) Its products must be in mass demand in a stable market.

There are, thus far, only three types of industry that seem to have possibilities of meeting these requirements.

First, there is the distillation or carbonization industry. Given some radically new tools and better utilization of tars, it may yet become a valuable part of integrated utilization.

Second, there is the fiberboard industry in its many ramifications, hard board, soft board, and medium board. Thus far, this sort of manufacture has been adapted mostly to large production units but successful small ones exist. There appears to be a possibility of replacing capital costs by labor costs in the small unit and producing a standardized fiberboard that can be marketed in much the same way as lumber. Also, processes are in the immediate future that will be quite uncritical of the kind of wood supplies.

Finally, some of us think the wood-sugar industry may play a significant role in mass consumption of low-grade wood. Technical problems seem well on their way to solution. Economically, it appears feasible to produce crude industrial sugar at a little over a cent a pound from wood at $2 a dry ton. A dollar more a ton for wood means only a tenth of a cent a pound more cost for sugar. At $10 a ton, sugar would still be only 2 cents a pound, and at that price a woods clean-up becomes economically possible.

A major reason for looking upon wood as a raw material for chemical engineering processes lies in the simple fact that chemical differences are the least important differences within the two great groups of hardwoods and softwoods. Limb or trunk, knotty or clear, old or young, the wood can be used in chemical processing when utterly unsuited to many of the traditional methods of wood use.

Discussion

Mr. George M. Hunt (U. S. Forest Products Laboratory): Some of the points upon which Dr. Hall touches so briefly deserve more emphasis, particularly the great need for small-scale wood processing methods that can use low-grade or waste wood profitably. As he points out, progress is being made in developing fiber board plants small enough to be subordinate to a woodworking factory. More than one such plant is now in operation and others are planned. With good markets and good management these should succeed. Large tonnages of the various kinds of fiber board are needed and the amounts will probably increase rather than decrease.

Wood-sugar manufacture also offers the possibility of efficient production in relatively small plants, using most any wood species or character of waste. Here again the potential markets are very great for the sugar in the form of molasses as a supplementary feed for live stock, for the production of yeast, for alcohol production, or for manufacture into other chemicals.

These are only two examples of the kinds of small-scale processes needed. Possibly the wood distilling industry can be rejuvenated by new discoveries and improved methods so that it, too, can become a more effective tool than it now is for utilizing low-grade material. At any rate, it deserves the attention of the research chemists.

Present Day Trends in Logging

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Historical Developments

IN ORDER to look into the "crystal ball" and visualize just where the present day trends of the logging industry in the Pacific Northwest are going to lead us, it will be helpful to review the evolution and development in all phases of logging since the Pilgrims set foot on the shores of New England. The Pilgrims were loggers as a matter of sheer necessity. It was imperative that they cut the trees of the forest to build their log cabins and out-buildings, to build their fences and furniture, as well as to provide fuel for heat during the cold winter months. While the Pilgrims became more settled, with farming as their major occupation, other pioneers were rapidly covering the coast from New England to the Gulf of Mexico. New frontiers were set up and the cutting of timber rapidly progressed along all the Atlantic Coast, thence to the Alleghenies, the Appalachians, the Lake States, and onward to the Pacific Coast. During those early periods timber was generally cut at the site where it was to be used, or contiguous to streams so that it could be readily floated to its destination. The timber was handled by manpower, oxen, and horses, supplemented by sleds or crude wagons. Where it was too large to handle by these available means, trees were cut into the proper length for lumber and boards or planks were split out by sledges and wedges, and then transported to the place of use.

With the gradual spread of population over the whole United States, and with the essential requirements of lumber, logging became one of our leading industries. Many men chose logging as their principal occupation and followed the timber operations as they moved westward.

Earliest Logging Machines

Starting with the crudest form of Spanish windlass, various types of logging machinery and equipment were developed. One of the outstanding developments was the Dolbeer steam spool donkey, where one end of a cable was fastened to a log, a bight or mid-portion of the cable was wrapped several times around a spool, and the log was slowly pulled from its lay where it had been felled, to a site where it could be placed either on a skidroad or on a railroad car or dumped into a stream for further movement to the mill. This was the first application of steam power to logging. In the 30 years that followed, mammoth steam donkeys with multiple drums were devised to work as yarders, skidroad engines and loaders. Yarding engines were used to move the logs from the stump to a location where some other form of transportation was available.

The High Lead System of Logging

The next development was the high lead system of logging which was copied from various types of rigging used on sailing ships, and patterned somewhat after the rigging used in shipyards. The high lead consists of rigging a high tree, which has been topped, with guy lines, pulleys, and hauling lines to pull the logs over stumps and debris to a central place where they can be handled more easily and efficiently by other means of transportation.

With the high lead came the so-called two speed donkey which had multiple gears and frictions, permitting the machine to be operated at variable speeds. Also, several unique systems of logging cableways were put into widespread use.

Electric-powered logging machines were developed in the early twenties. These had a limited field of application because of the difficulty in keeping high tension electric power lines up to the site of the logging machines.

Limit of Size Reached in Large Equipment

During the twenties, logging engines reached a limit of huge size and great weight with the development of the steel spar skidder mounted on railroad wheels, and the multiple drum slack skyline engine. In some instances these machines weighed in the neighborhood of 400,000 pounds, and it required the combined efforts of three or four locomotives to move such machines over steep railroad grades. Some of these steel spar skidders cost as much as $125,000 when fully equipped. These large machines had their greatest value in steep country where railroad construction costs were excessive and it was necessary to reduce the mileage of railroad to a minimum.

Early Use of Tractors and Internal Combustion Engines

The track-laying tractor, which had its beginning in the field of agriculture in California, was greatly improved during World War I, and was used in logging to a limited degree in the early twenties. This machine was destined to play an extremely important part in the development of modern logging, and will play an increasingly important role in the future.

About the same time internal combustion power was applied to logging engines, using both gasoline and diesel fuel oil.

Need of a Better Transportation System

As the timberline receded from the immediate vicinity of the building sites and streams, supplemental systems of transportation had to be devised. The first of these was a so-called skidroad or pole road where an elaborate roadway was built either of heavy timber cross skids or a semi-circular chute of fore and aft logs, over which saw logs could be pulled by an endless cable and taken relatively long distances for those days, say, one to two miles downhill to navigable waters. When this system no longer sufficed, railroads were called into use in the logging industry and the development of railroad tracks and railroad equipment formed an interesting phase of the business. The first locomotives were extremely crude and small in size, and with the increasing distance of travel from the mill or waterfront to the timberline, it became quite necessary to devise a type of locomotive that could climb steep grades of 6 or 7 percent, and could also go around relatively sharp curves. This brought into logging use the so-called Shay locomotive which had been widely used in the coal and ore mines in other parts of the country.

Railroads were gradually developed so that some of the major logging operations had substantial mileages of high grade track. Another idea was borrowed from the mainline railroads, and with the use of the Mallet compound cylinder locomotive on the logging railroads, it appeared that the acme of perfection had been reached in railroad transportation of logs.

However, other influences were at work, and while railroads were highly satisfactory for the hauling of large volumes of logs, their use was limited to relatively large tracts of timber. As the larger tracts were cut and a greater percentage of the timber remained in small tracts, there was a definite need for the development of some other system of transportation, requiring a much smaller capital investment. Since railroads were limited to maximum grades of 6 or 7 percent, it was necessary to cross over many sharp ridges and ravines and costly road building was necessary to reach many of the timbered areas, especially in the more rugged country. Where there is a great enough volume of timber and it can be funneled over a single route, next to water transportation, the railroad provides the cheapest possible transportation ever developed.

In the twenties inclined-cable railroads were used to haul logging machinery, cars, and logs over extremely steep grades and to reach high elevations. Cable-tramways were also used in some places. These forms of transportation were quite popular for a few years, but became obsolete as the heavy-duty motor truck was developed and found to be useful for the trucking of logs on steep grades.

Use of Automotive Logging Trucks

The logging truck was rapidly taking the place of railroads in many medium or small sized operations. Logging trucks were first used just after World War I, and their use increased rapidly as the tractor made possible cheaper road construction and filled the need of a more mobile and lighter type of logging machine. The mobility of heavy trucks and the fact that the same vehicle could run over both public

and private roads, and could operate on much steeper grades than a locomotive could, were definite advantages in its favor.

Rapid Development of Mechanized Road Building

Methods of road building were changing during this same period. While the early pioneers hauled their logs over dirt roads in the dry summer months or over the frozen ground in the winter months, such roads were impassable during the rainy season and for the period that the frost was coming out of the ground. All-weather roads in the early days consisted of the use of split timber or puncheon plank or very limited use of rock in the wheel tracks. Grading of roads was done by manual labor. This type of road building reached its peak shortly after 1920 with the Swede gangs that built many hundreds of miles of logging roads on a yardage or station cost basis.

Efforts were made at various times to use horses, scrapers, plows and other forms of equipment to build cheaper roads. The use of a steam donkey engine with cable drawn scrapers was the first application of power driven machinery to logging road building. Where railroad ballast was not available, some operators built all their railroad on trestle work, and had special bridge crews for the operation of pile drivers and for the construction of this kind of railroad.

Immediately after World War I, steam shovels on sectional railroad tracks were called into use to build woods roads. Prior to this time both truck roads and railroads were designed to follow the contours closely in order to minimize the volume of earthwork to be handled. This resulted in circuitous roads on which operating speeds were necessarily slow.

In the early twenties a few tractor-type, gas shovels were put into operation in the woods and the results were very gratifying. Our own Company was one of the earliest pioneers in using 1½ and 1¾ yard track-laying type gas and diesel shovels in the construction of logging roads. These shovels were capable of moving dirt, roots, and large logs at the lowest cost that had ever been attained. The use of this equipment was expanded rapidly.

Revolutionary Development of Logging Methods and Equipment

The most revolutionary development in logging was the application of the tractor to logging and the use of the tractor-bulldozer and carryall scraper to the construction of roads. The high degree of portability of the tractor-bulldozer and its flexibility and efficiency in building cheap roads, made possible the widespread use of the heavy-duty motor truck in the hauling of logs. The ability of the tractor-bulldozer to scratch out cheap roads also made it possible to tractor log in terrain which otherwise would have been too steep and rough for safe tractor operation. We need only to look back to the turn of the century and recall how gasoline was burned in huge fires in order to dispose of a hazardous by-product of the oil refineries and then observe the rapid development of the gas engine, to realize how much it contributed to the radical changes in all phases of logging.

Power Saws

The first power chain saws were built during World War I. However, it was only recently that satisfactory lightweight chain saws were developed, powered by air-cooled gas engines. This tool has materially lessened the burden of hard manual labor in the felling and bucking of trees.

Contributions by Many

A great deal of credit is due various equipment manufacturers, not only those who specialize in logging machinery, but many others who have brought valuable tools and equipment into the logging industry. Various public agencies such as the state and federal foresters have also contributed much to experimental work and intensive studies which have produced good results. Last and not least, credit should be given to the progressive, old time loggers who have developed many valuable tools and methods which are in common use today.

Present Day Trends

We have given considerable emphasis to the mechanical developments of the past several decades. We have pointed out the radical changes in methods evolved during that period, but we have by no means reached the peak of

all possible development. We are on the threshhold of a wonderful new era and many substantial improvements will be made. The next several decades will see progress equal to, or substantially greater than, that which we have witnessed in the past few decades.

Some 20 years ago most of the logging in the Pacific Northwest was done by a limited number of large operators. With the development of the tractor, bulldozer, and motor truck, there has been a radical shift to smaller operations. While this has resulted in the cutting of many small tracts of old-growth timber by a large number of operators, there has been a counter-balancing influence in the development of a substantial number of tree farm units.

As small trees are cut in thinning operations, the development of new practices in preloading and bundling will be needed, if the job is to be done economically. Such thinning cuttings will be necessary at intervals of approximately ten years in order to keep the remaining trees growing at their maximum rate.

More Constructive Planning

Managers, engineers, and foresters are making use of the latest developments and devices in the planning and management of timbered areas. Among these is the use of aerial photographs for the development of mosaic maps, stereoscopic pictures for the study of blowdown, dead, and diseased timber areas as well as the study of species and various age classes of timber in order to plan the proper time for cutting various areas. High grade topographic maps are also made from these aerial photographs, and such maps are invaluable aids to logging engineers in planning road systems.

Permanent Roads

Where motor trucks are used for log transportation, it is possible to plan a very dense network of permanent roads. By the use of the latest types of construction equipment, and by applying the principles of the mechanics of soils and of soil stabilization, roads are being built on a permanent basis in many tree farm areas. A number of operators have constructed private access roads from the timbered areas to navigable streams or to their mills. Plans are being made by the federal government to construct permanent forest access roads into large areas of presently inaccessible, overmature timber. The early construction of such major roads will make it possible to salvage large quantities of overmature timber which normally would be wasted. There is certain to be a substantial increase in the number of such roads built by private industry in the near future. Some of these roads are comparable to our better state highways, and all of the structures and improvements are built with the idea that they will last for long periods of time.

Working Conditions, Homes, and Social Conveniences

There have been substantial improvements in working conditions, home and community living conditions of the loggers generally, and the old time stag camp close to the stump has been rapidly disappearing. A large percentage of logging employees today are family men. With the shorter workweek and available spare time on the part of logging employees, the individual himself is giving more time and substantial effort toward developing his own rural home. Such homes have all modern conveniences, a garden, fruit trees, berries, and other subsistence items. Most such homes and developments are within a reasonable travel distance of well established communities with recreational and other social conveniences.

Tree Farm Movement and Better Forest Practices

For many years forward looking loggers have been leaving seed trees and seed blocks intermingled with their cutting areas, and have so managed their slash burning that today there are large areas of second-growth on many of the permanent tree farm areas and substantial areas will soon be ready for thinning and intensive management. Good roads provide a high degree of accessibility to these tree farm areas, and with the fast and mobile fire equipment which is being maintained in many areas, real meaning has been given to the KEEP GREEN MOVEMENT that had its origin on the West Coast.

A valuable impetus has been given to intensive forest management by the development during recent years of new uses for low grade logs of various species. The continued and economical use of such low grade material is

filling a long felt need and is making it possible for loggers to operate their timberland holdings so that there is every reasonable prospect that our forests will be brought up to the high degree of management which has long characterized certain European forests. The close utilization of material which was previously wasted has resulted in an increased forest inventory. With increased accessibility to most of our growing stands of timber, it will be the custom to salvage all dead, down, diseased, deformed, and depressed trees so that those which are left will have optimum growing conditions and thus produce the largest possible volume of timber from any given piece of land. Every effort is being made to place all cutover areas into immediate productivity either by natural means or by artificial means such as hand planting of seedlings or seeds whenever necessary.

Where topography, rainfall, and soil conditions permit, considerable logging is done on a tree selection basis. In much of our West Coast Douglas fir area, especially during the rainy season, conditions are not too favorable for continuous tractor operation. Frequently, yarding drum units are applied to tractors and the units are used as high lead yarders in logging clear-cut staggered settings. Where logging is done by cutting on staggered settings, the remaining areas provide an abundant seed source for natural reproduction.

Closer utilization has reduced the volume of inflammable debris on the logged-over land. Spot burning of slash piles, landings, and strip areas to break up the continuity of slash areas, are valuable aids in minimizing fire hazards. With intensive road coverage, modern fire equipment, and an efficient fire protection organization, accidental fires of serious proportions are reduced to a minimum.

Mobile Logging Equipment

We expect to see practically every type of logging machine, whether it be yarders, interlocking skidders, or loaders, mounted on pneumatic tires or track-laying type of wheels. Steel spars suitable for a high lead operation will be mounted on wheels so that all yarding and loading equipment will have the greatest possible degree of mobility. Tractors, trucks, and the application of wheels to almost every kind of equipment or tool used in logging operations will make possible frequent and economical moves. The wider application of the mobile crawler-shovel or rubber-tired type of loader will make it economical to use more frequent loading places, with the result that the distance of log movement from the stump to the truck will be materially shortened. The mobility of all kinds of equipment will have a major effect not only on every type of logging but will have particular value in tree selection logging, such as in thinning operations or in logging the overmature and decadent scattered old-growth trees from stands which are otherwise young and healthy.

Conclusions

The present trends in logging are:

1. The widespread use of airplanes for fire protection, aerial photography, tree disease and insect control, seeding and general reconnaissance.
2. Intensive road systems of more permanent construction.
3. Improved mechanical equipment and the use of new inventions and tools.
4. Greater mobility of all machinery and equipment.
5. Closer utilization and salvage of all grades and species of trees and greater use of forest by-product materials.
6. The application of intensive forestry to grow the maximum crops of timber in the shortest possible time.

THE ULTIMATE GOAL IS:

Sustained yield in forest products, water supplies, wildlife, scenery, communities, homes, payrolls, permanent employment, and the production of goods for the comfort and convenience of everyone.

FOREST PRODUCTS RESEARCH SOCIETY

Pulpwood Logging Developments in Eastern Canada

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This paper notes the improvements in pulpwood logging technique and the increasing mechanization of logging in Eastern Canada; also the advance in training of woods labour, its higher remuneration and improved conditions. It is observed that large-scale operations are conducted in this region on government-owned property, and that insecurity of land tenure is retarding full implementation by the industry of its forest policy, aiming at sustained-yield forest management.

CANADIAN pulp and paper companies use about nine million cords of wood annually—chiefly spruce, balsam fir and jack pine. In the East the cut averages about ten cords per acre and the wood usually runs from 60 to 140 four-foot bolts per cord. Pulpwood is cut mostly in four-foot lengths or as 12- to 16-foot logs, although eight-foot lengths are popular at the head of the Lakes.

Logging commonly consists of four major steps: Cutting, chiefly in the fall and winter, until deep snow; skidding, simultaneously with or soon after cutting; hauling, principally in winter; and river driving. Typically, the work is dependent on the muscle power of men and horses until the wood is placed on the ice or in the water. However, this conventional pattern is being altered by increasing efforts to mechanize logging, to do the work whenever the labour supply permits, and to minimize risks due to the capriciousness of the weather.

Improvements in conventional technique.—Unless adequately directed, logging represents a haphazard mixture of efficient practices with those wasteful of effort or unsafe to the workers. Through a series of research projects, pulpwood cutting, skidding, hauling and river driving have been analysed from an efficiency viewpoint, to separate "the husk from the grain"; and, as a standard guide to sound practices, manuals have been prepared for the use of supervisory personnel (1, 2, 3 and 4).* They deal with proper planning of work, efficient and safe execution of its various steps, the choice and maintenance of tools and equipment, the handling and care of horses. These manuals also give some leads for further improvement in technique.

Instruction of woods labour is being provided in many cases on the basis of the above studies, through illustrated booklets for use by workers (5, 6 and 7) and through the services of logging efficiency instructors. The use of visual aids—illustrated posters, instructional film strips, moving pictures—is limited but increasing.

Mechanization of logging, a serious need, is receiving increasing attention. More of the available machinery that is suitable is being used, and endeavours are being made to develop some new machinery and techniques for needs that the existing equipment cannot properly satisfy (8).

Main roads for portaging of supplies and for truck hauling are built and maintained by machinery, much better than formerly. This practice is spreading to lesser roads. Most portaging, almost all summer hauling of wood, and an increasing amount of winter hauling over main roads, are done by trucks with occasional use of tractors. Yet, sleigh haul with horses—usually single—still is the most common practice, not only on feeder roads but on main hauls of comparatively short length. Many types of mechanical equipment are used or experimented with in connection with loading and unloading (9). However, most of this heavy work is still done by hand.

Cutting and skidding greatly need to be mechanized, but hardly more than one or two percent of this work is done by machinery. So far, probably more satisfaction has been obtained from portable slashers than from chain motor saws, although the use of the latter is

* The numbers shown in parentheses refer to pertinent bibliography appended on pages 8 and 9

most likely to increase greatly with the introduction of lighter and more "foolproof" models, and with improved handling of this equipment.

Very few power-skidding operations have passed the experimental stage, but indications are that both cable and drawbar skidding will be increasing, gradually replacing horses. In rough terrain, chutes are used to an extent, including portable types, made of steel or aluminum; and a few experiments with cable suspension chutes have been started. A simple method of skidding wood by gravity down steep slopes, over a wire suspended between a tree at the top and another at the bottom of the incline, is also being tested (10).

Aerial survey data are widely used in planning logging operations and steady progress is being made in perfecting their application (11). According to recent trials, helicopters will likely prove most helpful in many connections, when more readily available and at lower cost (12).

Woods workers are predominantly French Canadian. The treatment of labour by supervisory personnel that receives elementary instruction in pertinent principles of psychology (Job Instruction Training, Job Relation Training, etc.) shows a marked improvement over old-fashioned "bossing". However, new trends in industrial relations do not penetrate into the woods rapidly. This may be partly due to the prevalent jobber system. At the head of the Lakes, woods labour is unionized considerably; in the East, to a small extent. The problem of "jumping" is serious: The average period of men's sojourn in a camp is about a month. Some companies endeavour to provide for greater permanency of employment through adjustments in the annual logging cycle, departing from strictly seasonal operations. Establishment of permanent "forest colonies" as a source of stable labour is more discussed than acted upon. An interesting development in one district is a group of "co-operative camps" where the workers conduct the operation on a partnership basis, under contract, to the satisfaction of the paper company.

Living conditions of woods workers have been bettered greatly as a rule through improvements in camps and diet. Log camps still are common, but lumber buildings are used increasingly and portable camps are being introduced with success (13). Foodstuffs are almost always good but camp cooks often could be much better. Their proper training is an important problem. A study of feeding men in camps, conducted last year, paves the way for preparation of better cooked and balanced meals, waste elimination, and improvement of the men's eating habits (14).

Earnings of woods workers, formerly very low, have been raised to a relatively high level. The establishment of production standards for various kinds of work under any set of typical conditions is needed, to serve as a fair and definite basis for piece-work rates.

Effect of logging upon the future.—Practically all the above pertains to logging as harvesting of wood, from the viewpoint of our present needs. However, logging is not merely harvesting. It is a surgical operation upon a forest that may be beneficial or ruinous to its future, depending on how logging—particularly cutting—is being done. The choice of logging practice often determines the quantity and kind of forest products that will be available in the future.

Better fitting of logging to the needs of silviculture and forest protection is, in Eastern Canada, a matter of great importance. The steps already taken do not reach far enough and the progress is delayed by the lack of research data, of trained personnel and, in some cases, of determination to provide sufficiently for the future through extra effort and expenditure. I do not mean that the overall picture is negative but, like many other foresters, I regret that progress is not faster.

Under present cutting methods, natural restocking that is prompt and good enough occurs often, yet far from always. The percentage of spruce—the most desirable pulpwood species—is diminishing (15). Balsam fir and jack pine reproduce in most cases readily. Cutting softwoods in mixed forest, while leaving hardwoods as "unmerchantable," often leads to the death of old hardwood trees through exposure and also to an increased percentage of these species in the second growth. Cutting frequently amounts to taking in a single operation all, or nearly all, the wood that the operator regards as merchantable. Thus a considerable amount of immature wood is cut, and predomi-

nant one-purpose operations often leave, as mentioned above, some wood that with greater integration of wood-using industries would not be wasted. Fortunately, the tendency towards such integration is increasing. The practice of marking and selective cutting is rare indeed. Several regeneration surveys have been made recently, or are in progress, and there is an increasing trend towards examining cutting practices from a silvicultural point of view and towards searching for improvements.

With rare exceptions, the role of planting is negligible or nil. It should increase before long in the best suited areas through inviting possibilities being offered by mechanization of planting and by seed selection to produce superior stock.

Logging waste normally is rather small, yet the drive is being intensified for its further reduction. While readily accessible forests are often overworked, in distant regions great losses of wood are sustained through overmaturity or the impossibility of salvaging timber killed by insects or fire. A campaign for road construction to open comparatively remote districts should considerably reduce such losses —if this campaign proves effective.

The forest policy outlined about two years ago by the Canadian Pulp and Paper Association (16) marks the way, in respect to logging, for needed action with regard to both the increase in the efficiency of work and the safeguarding of the future wood supply for the industry. The bulk of the forests operated by the companies are public forests controlled by the provinces and used by the industry under lease. Insecurity of forest land tenure is a heavy handicap to full implementation of the industry's forest policy and the placement of all commercially valuable forests under management on a sustained-yield basis. The companies are hesitant about making major investments in silviculture until their position with regard to forest use in the future is rendered sufficiently secure. A solution of this problem is badly needed.

Intensification of research is also essential for greater progress in implementation of the forest policy. Accordingly, the Pulp and Paper Research Institute of Canada has decided to extend considerably its program of woodlands research; and the direction of this work in the Institute, to which the author has been giving only a fraction of his time, has recently become his full-time responsibility.

Bibliography

Below are listed some of the publications that give specific information on the subjects merely touched upon in this brief report.

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2. Pulpwood Skidding With Horses. By J. F. Walker, D. R. Stevens and A. Koroleff. 137p. CPPA and PPRIC*.
3. Pulpwood Hauling With Horses and Sleigh. By A. Koroleff, J. F. Walker and D. R. Stevens. 159p. CPPA and PPRIC.
4. River Drive of Pulpwood. By J. F. Walker, W. D. Bennett, G. E. LaMothe, C. R. Silversides and A. Koroleff. 256p. CPPA and PPRIC.
5. Woodcutter's Handbook. By A. Koroleff. 23p. CPPA.
6. Teamster's Handbook. By A. Koroleff. 26p. CPPA.
7. Forest Conservation—Practical Pointers to Woods Workers. By A. Koroleff. 33p. CPPA.
8. Logging Mechanization. By Gordon Godwin. 6p. CPPA.
9. Mechanical Loaders. By A. H. Burk. 8p. CPPA.
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13. Design and Construction of Logging Camps. By C. R. Silversides. 19p. PPRIC.
14. Feeding in Logging Camps. By Dr. D. L. Gibson. 53p. PPRIC.
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16. Statement of Forest Policy of the Pulp and Paper Industry of Canada. 4p. CPPA.

* CPPA stands for Canadian Pulp and Paper Association (Sun Life Building, Montreal), and PPRIC for Pulp and Paper Research Institute of Canada (3420 University Street, Montreal).

TECHNICAL SESSION II

Friday Afternoon, October 31, 1947

General Subject: Engineering Aspects of Wood Use

Chairman: James F. Hamilton, Technical Service Director, Perkins Glue Company, Lansdale, Pennsylvania *(Northeast Regional Board Member, FPRS)*

Recorder: Thomas R. C. Wilson, Consulting Engineer, Madison, Wisconsin *(Secretary-Treasurer, FPRS)*

Note: The paper USE OF HIGH FREQUENCY IN WOODWORKING, by Paul B. Zottu, Consulting Electronic Engineer and Physicist, Electronic Heating Associates, Newton, Massachusetts, was presented extemporaneously and has not been made available for publication.

FOREST PRODUCTS RESEARCH SOCIETY

Influence of Building Codes on Postwar Wood Construction

L. P. Keith

Manager, Chicago Office, National Lumber Manufacturers Association

The problem is more properly the effect of postwar codes on present types of wood construction, because efforts are being made to ignore experience and to glorify mere incombustibility. Instead of providing codes for the wise use of wood in accordance with experience, there are those who would eliminate its use.

Code proposals are already being suggested on such a basis. Examples are given of some of the regulations contemplated by those developing codes. Nevertheless, sane thinking still predominates, as evidenced by several citations, and sane building laws are being enacted.

Such codes will make possible the application of any developments in the use of wood, just as connectored trusses and glued laminated construction have been permitted. Prefabricated construction, however, has found codes to be obstacles, not so much because of the provisions as for the interpretation to accept what is wanted or to prohibit what is not wanted.

The effort should be to promote sane codes; these taking care of present wood construction would permit any worthwhile developments.

"POSTWAR wood construction" almost involuntarily evokes thoughts of the uses of wood in some of its newer forms made glamorous by publicity during the recent war. Because forecasters were extremely visionary, our imagination is quite likely to anticipate very novel construction, even though details might be somewhat uncertain. Extending these musings, we would probably arrive at something which might use some form of a wood product not even known at this time in some variety of weird building which perhaps would be unpacked from a suitcase and erected instantaneously with practically no labor at all, fully equipped with all essentials.

Now, I do not know what effect building codes will have on vague, dreamy postwar wood construction of the remote future, but I doubt if many of them as now written would seriously restrict the use of any meritorious development. Few codes are as obsolete as they are generally alleged to be. Most codes provide for acceptance of new materials, new assemblies of old materials, and new systems of construction. Where this is not the case, communities generally find a way to make legitimate what is wanted, if safety requirements are satisfied, and conversely to keep out what is not wanted for fear of reduced property values, or fear for jobs, or for this and that reason, none of which may be the proper concern of building law. For these reasons, present building codes do not in general offer a threat to postwar wood construction, whatever it may be.

Rather, our concern should be turned to the effect of postwar building codes on prewar types of wood construction, for efforts are being made to have new Gods replace the old.

It seems that for decades we have been worshiping at wrong altars. We, meaning communities adopting building codes, have thought that years of fire experience with full-size models under actual conditions, plus professional knowledge of the strength and uses of materials, combined to give us a rather reliable approach to the goal of protecting the public safety. Buildings of heavy mill construction, housing almost the entire range of industry, have been fire-tested again and again for more than 100 years and their superb performance under fire conditions gave birth to the very significant name "slow burning." The almost half century of experience of six-story wood-joisted apartment buildings in New York City, built under the New York State Multiple Dwelling Law, yielded a fire safety record of fatalities being practically nil as far as construction was concerned (1). A record of 7,459 fires in sprinklered industrial buildings substantiated the statement that automatic sprinkler protection, properly installed and maintained over combustible occupancy, reduces to

—Courtesy of The Austin Company, Engineers and Builders.

The largest timber factory in the world, a wartime structure, used Teco connectored trusses for spans up to 150 feet, supported on glued-laminated wood columns, 17 by 34⅜ inches in cross section and 54 feet long, formed from random-width boards (1 by 4 in. and wider).

a common level the probable extent of loss by fire in industrial buildings having masonry walls—whether or not the interior construction is combustible or non-combustible (2). These are only a few of the records demonstrating that wood can be and is used with entire safety in building construction.

Notwithstanding the knowledge gained of how to use wood wisely, we are suddenly told that experience is a false God, unscientific, and no longer to be trusted; we should learn not to use wood, a thought which meets with the almost unanimous approval of our competitors. Combustibility, over night, becomes the most wicked of all sins.

We are told we must go to a new altar where the God of Incombustibility is enthroned. The virtue of a material or of an assembly of materials, it seems, lies solely in the ability not to burn or transmit flame for a stated time period when placed in a laboratory test furnace. Buckling or collapse under moderate temperatures is not regarded as even one of the little sins; it is just a little weakness of no consequence amongst friends.

The basic pronouncement of this new ideology in code writing is: The fire hazard is directly proportionate to the potential fire volume. Expanded, the statement becomes: The danger to life is directly proportionate to the pounds per square foot of combustible material occurring in the contents and in the construction of a building. The theorizers promoting this philosophy regard it as being only unfortunate that fire history experience does not confirm their opinion. Heavy timber mill construction, as an example, with more than three times the combustible material of a building of ordinary construction, aggravatingly refuses to be as hazardous as some construction entirely incombustible. The fire volume in the Cocoanut Grove fire was low, but the hazard was great. Similarly in the Natchez negro dance hall, the hazard consisted solely in dried Spanish moss and locked exits. The recent hotel fire catastrophes showed no relationship between the amount of combustible materials involved and the life hazard. The demonstrations merely confirmed a long recognized fact that given a tremendous updraft, as provided by a tall

chimney, a small blaze will develop with extreme rapidity into a big one. Each of the hotels had these chimneys in the form of open stairwells. Of the several fires of this nature, the General Clark Hotel in Chicago involved the most combustible material, yet the coroner's jury, composed of consulting engineers and construction experts, held it highly improbable that a single life would have been lost if the stairwell had been enclosed. The Winecoff Hotel had the least combustible material but the greatest loss of life.

Since fire records are so disobliging as to refuse to confirm the theory, the remedy of the reformers is not to change theory but instead to discredit experience. The next step is to assume there will be no fire extinguishment. In fact, the representative of an incombustible material industry in a printed book berates the fire underwriters for placing so much value on water supply, fire departments and fire alarm systems. The so-called rational approach to building codes seems to have considerable sand in its foundation but, nevertheless, it may influence some postwar codes; it has already led to numerous proposals which have received serious consideration.

Naturally, hotels were the first target. Although none of the catastrophes occurred in buildings with enclosed stairways, an organization of fire chiefs would limit the masonry-walled, wood-joisted hotel to two stories. The hotel proposals were made more acute by the hysteria always following a public tragedy. This hysteria went so far last Spring that a sub-committee preparing material for submission to the President's Conference on Fire Prevention actually, and in all seriousness, intended to propose that no wood furniture could be used in a place of public assembly or where people are domiciled at night.

Wood sash would be barred from buildings more than 150 feet high, although the amount of combustible material contained in them would be almost minute when compared to the combustible contents of the building occupancy. It leads to rather a ridiculous situation where one building 149 feet in height could have wood sash throughout, but the building next door 18 inches higher would be restrained from having them. (This, actually, is New York City building law, but the same proposals have seldom met with serious consideration elsewhere until recently.) The idea is not prompted by need developed through experience, but solely on conjecture.

Because fatalities, due to highly flammable decorative materials and locked exits, have been high in night club fires, it is proposed to limit restaurants with wood joists and wood stud interior partitions to a very small area—one much less than the average size lot in a business neighborhood. In these localities, small business buildings of two or three stories of wood joisted construction commonly cover a lot, or two lots where the frontage is narrow. To limit a restaurant to less than this unit area means that an owner of such a building could not rent to a restaurant if it be a new tenant. This seems absurd, since the limitation is imposed merely on the opinion that any restaurant might become a night club and that these have had fatalities for other reasons than materials used in their construction. These reasons are obviously of doubtful validity; it would seem much more practical to be able to rent such buildings for restaurants, drug stores, beauty shops, hardware stores or any of the occupancies which go to make up a neighborhood business district.

Churches are places of public assembly and, under the so-called rational approach, wood roofs would be permitted only on those of very small size, although I do not know of any fatalities because of fires in church roofs. Thus, architects could not use glued-laminated Gothic arches or hammer trusses to any reasonable extent.

The theory that incombustible construction is in itself so superior that it is entitled to special privileges becomes somewhat silly when we consider the case of masonry-walled construction with joisted floors. The interior framing may be of wood or combined in varying degrees with incombustible members. As long as one single combustible member remains, it is regarded with suspicion by the proponents of the new ideology. As soon as this last sinful piece is replaced with a virtuous one of metal, the building becomes glorified in the twinkling of an eye. The assumed additional safety is rewarded with another story in height and from 25 to 30 percent increase in area. One shudders at the complications which could arise in

Timber framing has been used for church roofs throughout the centuries without hazard to worshippers, yet some would forbid its use in edifices except those of very small area.

the reverse process of replacing a piece of material weakened by corrosion with one of wood. This one piece would make it an illegal building.

Fortunately, there is evidence that sane thinking still predominates in making our building laws. The last several sessions of the New York Legislature have seen attempts to limit wood-joisted multiple dwellings to three stories in height; the 47 year experience record with six-story apartments of this construction outweighed arguments based on unconfirmed opinion. Remedial hotel legislation in Chicago and Atlanta, where the worst of the fatal hotel fires occurred, was limited to reasonable regulation; the target was public enemy No. 1—the unenclosed stairwell. Code committees, developing building law for their respective communities, have refused to be stampeded in rejecting experience-proven safe construction; they have modernized their codes by removing artificial and needless restrictions and by making adequate and specific provision for the use of new materials, but have not accomplished the latter by sacrificing known materials. These cases cause us to believe that sane codes will continue to be the rule and not the exception.

This brings us back to the original subject, which was brushed aside at the start somewhat facetiously, in order to show the necessity first of assuring a place for wood construction as we know it today.

Just what "postwar wood construction" will be in a few years is hard to say. Research will continue to produce new wood products and better methods of using both the new and the present forms but, no matter what the developments are, we would not anticipate sane codes would be a barrier. With one exception, they have not in the past been stumbling blocks to improved uses of wood.

Glued-laminated construction and connectored trusses are results of research. They are still modern but no longer new. They were new a few years ago, but codes were not a serious problem as far as their first use was concerned. For example, neither construction is mentioned in the Chicago Building Code, but the first connectored trusses and the first glued-laminated arches were used here more than ten years ago, long before their worth was so fully demonstrated in war construction. Nor do I hear of difficulties elsewhere under similar circumstances.

The story of prefabricated houses, however, is quite different. Earlier in this paper, I noted that a way is generally found to make any construction "honest" if it is wanted, or to prohibit, on the other hand, anything which is not wanted. It is surprising how so many communities find it possible to use their code in either direction when it comes to prefabricated houses, although I have been unable to accommodate those who would have me write a clause elastic enough to indulge their personal likes as well as their prejudices. Most prefabricated houses, at least those made by reliable manufacturers, are well above the minima in requirements for safety, yet the going has been difficult for sponsors, not so much because of the codes themselves, as on account of interpretations made to suit the wishes of various groups. Public acceptance governs, rather than codes, and the best answer is education.

The best program would be to keep building codes well within their proper sphere of prescribing the fewest restrictions necessary to keep people from getting hurt, and within such limits as to provide freedom of competition for all the materials. If this is carried out, we have nothing to fear from postwar codes or for postwar wood construction.

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(1) Bureau of Records Fatality Statistics of the State of New York Tenement House Department, 1922–29: "The record of deaths by fires in Tenement Houses includes deaths from all causes such as individual accident, children playing with matches, re-entering or remaining in the building to obtain possessions, paralysis from fright and other causes. There has never been a life lost by fire in a New Law Tenement due to conflagration of the building or to any defect in the construction or arrangement of the same." (New Law Tenement Act was passed in 1901.) Data compiled later elsewhere brought the record through 1945, with the result of one death in 33,000 fires, a record not surpassed by fireproof construction.

(2) "Lessons From Major Industrial Fires"—Sixteenth Annual Fire Department Instructors' Conference, Memphis, Tennessee, January 11–14, 1944. Published and Distributed by The Educational Committee, International Association of Fire Chiefs.

Discussion

Harold S. Crosby (Northern Hemlock and Hardwood Manufacturers Association): The influence of building codes on immediate postwar construction, it seems to me, is rather obvious. Certain construction, particularly housing, where building officials have relaxed standards as a matter of expediency, will undoubtedly come in for special attention. This includes not only wood, but other materials. There are buildings of unprotected metal with inadequate clear space. There are converted and makeshift buildings with inadequate exits or fire protection. There are trailer colonies with attendant problems of health and sanitation. I believe, that, when emergency conditions abate, there is going to be a stricter application of standards which we have been schooled and experienced to regard as adequate and reason-

able. If we regard "postwar construction" as applying to nebulous and exotic new types, I think the usual building code is sufficiently inclusive so that these may be built as they come into being. I heartily agree with Mr. Keith that public approval and popular demand will pave the way for acceptance of new methods and types of building. I do not look for the general adoption of arbitrary standards which will tend to militate against the intelligent use of wood, or any other material for that matter.

John D. Ritchie (Douglas Fir Plywood Association): The wood industry, as a whole, has not given enough attention to the formation of building codes and the setting up of standards, particularly with reference to fire resistance. More time should be given by members of the wood industry to acquainting themselves with these matters, in order to prevent wood being legislated out of certain types of construction, by pressure of competitive products rather than actual test data.

FOREST PRODUCTS RESEARCH SOCIETY

Progress in Wood Construction

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Recent progress in wood construction and some of the problems still to be solved are described. Wartime construction is seen to have accelerated the widespread adoption of existing techniques, but to have contributed little that was basically new. The compilation and dissemination of existing information was a decided step forward. Use of stress-graded lumber was given an impetus. Timber connectors have become standard in framed structures. Glues and glued-laminated structures were both improved and found widespread use. Timber-concrete composite decks made their appearance. Plywood experienced phenomenal growth.

Many problems remain. The bases of the determination of working stresses are open to some question. Stress-grading procedures are inadequate for members used in framed structures and for common grades of lumber. Design procedures for nails are deficient and other fastenings could be improved. Much room exists for further improvement of glues. Low-grade and short-length lumber is not adequately utilized. Wood waste offers a continuing challenge. Treatments against fire, decay, and shrinkage, and finishes for wood could be much improved.

THIS discussion of progress in wood construction will first review briefly the accomplishments of the immediate past and then examine some of the areas in which further research and development are needed.

Significant new developments originated almost entirely before the war. Wartime construction telescoped into a few years and on a large scale the progress in applications of newer techniques which normally would have taken much longer, but it contributed relatively few new methods or devices.

Perhaps one of the most important wartime contributions was the careful compilation and condensation of a mass of information respecting timber engineering which had heretofore been scattered through numerous miscellaneous publications. When War Production Board Directive 29 appeared, specifying emergency stresses, fabrication, and methods of design, structural engineers for almost the first time had a concise manual in which the important developments in timber design were summarized. The manual had its shortcomings, but its continuance in peacetime as recommended by the lumber industry attests its value.

The war accelerated the acceptance and appreciation of the principle of stress-grading lumber and designing for specified stress grades. This in itself was a major step forward and helped to eliminate much of the confusion, uncertainty, and wastefulness inherent in merely designing for the poorest stick in a lot of miscellaneous lumber. Stress-grading was not a new principle, but the war helped to drive it home among engineers and users. It remains to have building codes generally adopt the same principle.

In the early thirties a series of new devices called timber connectors was introduced into the United States from Europe. Their acceptance at first was slow, but by the outbreak of hostilities they were quite familiar to the construction industry which employed them in increasing numbers. The unprecedented wartime expansion of timber construction put millions of connectors into use and made their acceptance so widespread that they are now virtually standard in the design of framed structures. A step forward occurred during the war when new principles for determining spacings were introduced as the result of research begun before Pearl Harbor. An improved form of split-ring connector was also introduced during the war.

Glued-laminated structures, including arches, beams, and similar members, often massive and of shapes unattainable in solid lumber, were developed but not widely used before the war. Phenol, resorcinol, urea, and melamine glues, individually and in combination, supplemented the caseins commonly used, largely removed the restrictions imposed by limited water-resistance and allowed laminated wood to be used with confidence under conditions of extreme exposure. Long arches for hangars,

Fig. 1.—Bridge built for U. S. Navy at Norfolk, Va., with composite creosoted timber-concrete deck. The bridge is 286 ft. long with a 30-ft. clear roadway, and was completed and opened to traffic in 13 days. Concrete was in two pours, one either side of a longitudinal construction joint. There are no transverse joints in the deck.

chords of large bowstring and other curved trusses, massive timbers for long spans and heavy loads, and smaller arches for barns and similar structures are examples.

An entirely different type of laminate is the combined timber-concrete deck for highway bridges, docks, warehouses, and similar structures. The lower portion of the deck, usually treated, is similar to conventional laminated plank. The upper portion is concrete. The two are made to act together by small metal "shear developers" and "uplift spikes". Depending upon the bending moment, either the timber or the concrete is stressed in bending tension or bending compression. Reinforcing steel is reduced to a minimum and concrete forms are eliminated. The concrete contributes a wear-resistant surface, the wood imparts impact strength.

Plywood, of course, is not a new material but the advances of the past 20 years have resulted in a spectacular increase in both the volume and diversity of application. As in laminated wood, the new adhesives have removed many of the limitations which previously circumscribed the use of plywood. Other papers in this series will deal with plywood in housing; it will be sufficient to indicate that prefabrication has made extensive use of plywood, often employing the "stressed-skin" principle; that plywood is widely used in place of sheathing, roofing, and subflooring; and that "dry-wall" construction employing plywood and other wallboards has made rapid progress. In

heavier structures, plywood has been widely employed for the webs of wooden composite girders and as gusset plates in heavy timber trusses. It has become standard in concrete forms. Other miscellaneous uses are too numerous to mention.

This brief account records an impressive list of achievements in wood construction. A closer examination, however, reveals large areas in which considerable improvement is possible, and still larger areas in which little has been accomplished but in which the promise is great. These can only be briefly mentioned.

1. Stresses. In establishing stress-grades account is taken of the natural variation in strength of wood, the probable depth and form of a structural member, duration of load, ignorance of actual loading conditions, and the weakening effect of defects. Perhaps the biggest individual factor is duration of load, which commonly involves a stress reduction to approximately $\frac{9}{16}$ for long-continued loads. It is based, to the best of the writer's knowledge, upon bending tests conducted a number of years ago with centrally loaded beams. In such beams both horizontal shear and bending stresses are induced. When heavily loaded over a long period of time the beams continue to sag at a decreasing rate, and if heavily enough loaded they eventually fail. Commonly, shear deflection and true bending deflection are lumped into one overall figure from which an apparent modulus of elasticity is derived. In practice, no account is taken of duration of load in assigning the apparent modulus of elasticity, but working stresses are reduced for long-continued loads to about $\frac{9}{16}$ of the short-time (5 minute) strength. This is true of any kind of structural member—beam, girder, strut, or axially loaded member of a truss. It would seem that the application of a large reduction factor, based only upon a bending test involving both shear and bending stress, is open to question when applied to members in which shear is negligible. Some evidence, although very meager, indicates that when horizontal shear stresses are absent creep does not occur until the proportional limit in direct stress or in pure bending is passed, that creep caused by horizontal shear is responsible for the continuing deflection of beams under load, and that this creep may be an important cause of the eventual failure of such a beam. If so, we may be penalizing members which are subjected only to direct stress. Research could profitably be conducted to determine the time-load behavior of wood in pure bending, axial tension and compression, and in horizontal shear. The results might have a direct bearing upon the fundamentals of all engineering design in wood.

—Photo by Timber Structures, Inc.

Fig. 2.—Erection of glued arches for radar test laboratory; span 80 feet, height 78 feet, spacing 16 feet 8 inches. Each arch is 10 by 31 inches in cross section, and made of 1⅜-inch laminae.

Closely related to creep is relaxation. This has been inadequately studied, but is probably responsible for a great deal of redistribution of stress among and in the members of a structure. It may account for the anomalous behavior observed in bent laminated members, in which high initial bending stresses induced in the individual laminae seem to disappear, permitting the member to carry heavier loads than would be expected.

Stress-grading practice needs improvement. Grades are established for beams and stringers, joist and plank, and posts and timbers. In the first two categories, large defects like knots and pitch pockets are unimportant near the ends of members. Trusses are commonly framed of joist and plank and it frequently happens that large defects occur where the members are

fastened together, the very place where the lumber ought to be sound. Grading procedures should take these uses into account.

Something needs to be done about allowable stresses in the common grades. No. 1 Common, for example, is often relatively clear, yet no stresses are assigned because certain important strength characteristics like slope of grain are ignored in grading. This seems a wasteful procedure from the engineering standpoint and with more engineering design going into housing, for instance, the old rule of thumb governing the use of the common grades are inadequate.

2. *Mechanical Fastenings.* Good progress has been made in mechanical fastenings, yet the most widely-used fastening of all, the common nail, cannot now be adequately designed. A good deal is known about the holding power of nails, but one of the most important factors of design—the spacing and end and edge distances—is inadequately covered by unsatisfactory specifications saying that nails should be so placed as to avoid undue splitting of the wood. This tells the designing engineer practically nothing. Nailed trusses and trussed rafters for light structures like housing are being increasingly employed. We should be able to design them properly.

3. *Glues and Gluing.* In spite of the rapid advances in glues and gluing techniques, a great deal still needs to be accomplished before their full promise can be realized in construction. The principal criticisms are the following:

a. Adjoining surfaces have to be too closely matched.

b. Pressures required to achieve high strength are too great.

c. Room temperature setting glues take too long to set, requiring excessive time under pressure.

d. Very few of the good glues will set at lower than room temperature.

e. Room temperature setting glues have too limited a pot life.

f. Some of the better glues require fairly close control of moisture content in the wood.

g. The good glues cost too much.

h. Advanced techniques, like high-frequency heating, are difficult to use in construction.

This list practically constitutes, in reverse, the specifications for a good construction glue. Very much needed is an inexpensive, low-temperature setting glue, able to bond both dry and reasonably moist wood, having long pot life and open assembly time but setting rapidly in the joint, requiring only moderate pressures, having good gap-filling characteristics, and being resistant to all sorts of exposure conditions. This is a large order, but until it is filled the full potentialities of glued-wood construction will not be realized. A number of glues partially fulfill these requirements, but none now available completely meet them.

4. *Low-grade and short-length lumber.* Many of the advanced techniques in wood construction do little toward the utilization of the large quantities of low-grade and short-length lumber now produced. Plywood needs large high-grade peeler logs. Stress-grading makes better use of the relatively high-grade lumber used in engineering design, but there is a lower limit to the number of defects permissible in engineering and construction lumber. Glued-laminated members would seem to offer an excellent solution, but the requirements of scarfed joints and pregluing of individual laminae into full-length pieces carefully planned to thickness make the wholesale use of short-length pieces unprofitable. Knotty and otherwise poor material is not easy to plane to the tolerances required for good gluing, and many glues do not stick well to knots, pitch pockets, and other defects.

Nevertheless, with glues having the characteristics called for above, real progress could be made in the utilization of low-grade and short-length lumber. Elementary mechanics reveals that in many structural elements the zones of high stress are limited, and that large portions of such elements—beams, slabs, arches and the like—could employ much lower-grade material than the zones of high stress. In these areas, if the right glues were available, sawn rather than planed stock, short pieces butted rather than scarfed together, and knotty or otherwise low-grade stock could be employed

—*Photo by Timber Structures, Inc.*

Fig. 3.—Bowstring trusses, with 202-foot span, glued-laminated top and bottom chords. Trusses are 30 feet on centers; all connections made with split-ring timber connectors.

and constitute the bulk of the member. Furthermore, large members could more easily and quickly be assembled in the field with simple equipment, making for economy in engineering design (two-hinged or rigid rather than three-hinged arches, elimination of splices, etc.) and economy in construction. Similarly slabs or sandwiches consisting of relatively thin, strong skins and relatively thick cores of low-grade and short-length stock might become economical to produce for partitions, walls, floors, and other uses where a full-thick slab would replace the usual structure consisting of ribs and covering. Obviously, both research and development are needed to make these laminates practicable, but the possibilities are there.

5. Wood waste. Wood waste in its various forms constitutes the greatest output of many wood-consuming industries. The construction industry would welcome any acceptable board, slab, panel, or sandwich, in which wood wastes such as sawdust, shavings, bark, chips and fibers are utilized. The various exploded wood, pulp, and similar wallboards have found ready acceptance. Boards consisting of chips, shavings, and sawdust bound together with synthetic resins, pulp and other binders are being watched and tried with interest. Chemically converted materials, such as lignin and wood-waste plastics, will find acceptance. All, of course, must meet the highly competitive situation existing in the construction industry.

6. Treatments and Finishes. Fire resistance, decay resistance, and minimized shrinkage are still three of the most important problems in wood construction. Fire resistance is especially important where thin wooden members are used with both sides exposed, as in plywood wall coverings and thin members of framed structures. Progress has been made in all three fields, especially in fire and decay resistance, but the perfect answers can hardly be said to have been found. Control of shrinkage is feasible but hardly economical today. Closely

coupled with it is rapid and economical seasoning without degrade. Chemical seasoning and high-temperature seasoning in special environments are promising but not by any means perfected. High frequency is too costly.

Many of the prefabricated housing schemes concocted by amateur enthusiasts concentrate on methods of panelyzing the frame, forgetting that by ordinary hand methods the assembly of the frame and application of boarding are generally accomplished in a few days. Much more time is required just to finish floors, paint woodwork, and to carry on the other multitudinous finishing details which run up building costs. Improved methods of pre-finishing all items of woodwork, whether in prefabricated or conventionally built structures, would materially reduce the finishing period and thereby reduce carrying costs. Impreg may help. Resin-impregnated paper, fabric, or veneer finishes for plywood and other boards are promising. Compreg floor tile are intriguing but must be thin in order to keep costs down. Here again a fast-setting low-pressure adhesive would be most useful. High frequency may be one answer. Pre-finished flooring is not new, of course, but the general principle needs to be extended and better integral or surface finishes, able among other things to stand up under fairly rough handling during the installation of woodwork, need to be formulated.

Many other needed improvements in wood construction could be cited. These are some of the more obvious and pressing. The answers lie partly in research, partly in development, partly in engineering, partly in manufacturing, partly in marketing, partly in obsolescent practices in the building industry, partly in restrictive labor practices, partly in building codes, partly in slow public acceptance of new materials and practices. It must be admitted, however, that the lumber and construction industries have both been slow to carry on vigorous research and development programs. Compared with their total volumes, the effort spent has been extremely small. Many of the new techniques have come from outside. It is time these industries faced up squarely and aggressively to their problems. The rewards for their solution are great.

FOREST PRODUCTS RESEARCH SOCIETY

New Engineering Problems in the Design of Wood Prefabricated Homes

Clarence W. Farrier

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Prefabricated or manufactured homes involve new engineering considerations. The assemblies manufactured for erection into homes must be constructed with more precision than is customary in conventionally built homes, as the parts must be interchangeable. Weights must be a consideration in the manufactured house, as it is shipped to distant points for erection.

The manufacturer's name becomes tied in with his product and, with his heavy investment in plant and dealer system, he is very sensitive toward malfunctions in his product. With a wide distribution, his product may be erected where some parts of his house may be subject to temperatures as high as plus 150° F. or as low as minus 50° F. and humidities ranging from the eighties to as low as five percent. These requirements and conditions give use to a wide variety of new engineering problems, particularly in the field of hygrometrics and thermodynamics.

This new industry starts from scratch in many fields of engineering, as development work and the necessary engineering data are lacking. As this industry expands, it will need specialized products. Its volume will be large enough to justify material producers to develop these special products.

MAJOR differences are to be noted between the engineering problems involved in the design of wood prefabricated or manufactured homes and those which characterize the design of conventionally constructed homes. These differences arise from the requirement for a much greater degree of precision in the manufactured home parts and the fact that, in the home parts assembled in a factory and shipped fairly long distances to the site for erection, the weight of the assembled parts necessarily must be a major consideration.

Before discussing these problems further, it might be well to define what we consider as being a prefabricated, or what is better named a manufactured, home, since these terms are not clearly defined by present usage. In this discussion these terms apply to a home constructed of sub-assemblies which, when erected on the foundations, form a completely finished home. Such factory-produced assemblies, manufactured with the necessary precision control to make like parts interchangeable, are capable of being assembled into a home which is far freer of air infiltration than the usual conventionally constructed house. This property of the home makes a major change in the thermal and hygrometric engineering problems involved. Manufacturers of these homes, who tie their names to these products through wide advertising campaigns, are very sensitive toward malfunctions in even a few of their products.

Those who distribute their products over a wide area must design them to meet a wide variety of climatic conditions. In some locations, parts of the house may be subject to temperatures of plus 150° F.; in others, parts of the house may reach a low of minus 50° F. In one location of the high-temperature exposure, the relative humidity may be in the eighties, in another it may be as low as five percent. When the sub-assemblies are produced in the plant and sent to the shipping room, they may go to any of these widely varying climates. Each part must therefore be made to meet all extremes, as well as the infinite variety of climatic patterns in between. This sets up a severely selective screen through which the materials and methods used must be chosen.

The processes which are carried on within a home, such as cooking, washing, bathing and the like, all produce atmospheric conditions which are much more severe than in most other types of buildings.

The designer of the manufactured home now must necessarily approach his problem with a very meager supply of data at hand in those fields of engineering other than structural engineering. He has a wide variety of structural data which flows to him from other fields. If

he does his part to preserve and enhance the reputation of the company's product, he must know far more than is now generally known about the many combinations of conditions to which the materials are to be subjected and about the ability of the materials to serve their purpose under these conditions. He should be able to conduct accelerated tests and to evaluate the results in terms of field service, but even the facilities for such tests are meager and data for evaluating them are far more meager.

The manufacturer's problems also dip into the human engineering field. To cite a simple example, is the housewife going to continue to follow her past habits of cleaning, or is it going to be possible to change those habits in most cases? Her use of abrasive cleaning powders will limit the choice of finishes which can be used. This is but one of the infinite variety of human problems which confront the designer of the manufactured home, intended to meet the demands of that complex pattern of habits and relationships inherent in the American family.

The successful producer of the manufactured home in a competitive field must acquire all of this new collection of know how and data as quickly as possible. In the interim, his approach to the ideal will unfortunately be contrasted with the further advances made in other fields where the life of the industry has been long enough to acquire, through research, the necessary data—both basic and practical.

Many data which may serve as basing points can be found by searching through information obtained in other industries for a different but related purpose. For example, a study of the data obtained by the packaging industry on methods of moisture proofing packages throws more light upon the prevention of moisture migration than is available on the subject of vapor barriers in the house-building field.

Effective vapor barriers are very difficult to obtain in either conventional or manufactured homes. While some method of prevention or control of vapor migration is very important to the success of the manufactured home, it is particularly difficult to provide this when we know so little of the basic facts involved.

Under some conditions the moisture movement in and out of wood under different states of moisture equilibrium can produce dew points high enough to place in jeopardy other materials in the cooler parts of the space. We are beginning to find that the cooling and heating effect of changes in the status of moisture equilibrium are of importance. The available data on this subject are quite inadequate.

A home to be successful must do much more than fit together on the site and remain standing in position against the elements. It must also provide an enclosure where ideal conditions can prevail for that very important segment of human activity known as family life. No other structure has as varied and exacting requirements for performance as a home. All of us, living in the enclosures we call home, well know that those we now have are far from meeting these exacting requirements in full. Some defects we rationalize as being inevitable and consequently tolerate. Others we consider a constant source of irritation.

A prominent psychologist once told me that his theoretical place as head of his family was subconsciously challenged by other members of the household because the brass strip which was supposed to cover the joint in the kitchen linoleum was constantly coming loose and he, the pillar of masculinity in the family, was unable to fix it so that the members of his family would not trip over it. All of his accomplishments as a psychologist meant nothing as far as his honor in the family was concerned, because of this shoddy item incorporated in the construction of their home.

Another example of the type of problem where engineering and psychology must be coordinated is that involving the human tolerance to deflection in floors. It has been found that the very rigid floors in some fireproof apartments produce unnecessary fatigue to the housewife. There are even cases where inflamation of the leg joints has been blamed upon this floor characteristic. At the other extreme, the deflection of the floor may cause things in the room to rattle when one walks across the floor. This extreme deflection, while not necessarily dangerous, mitigates against a feeling of security.

The present standard for deflection incorporated in many building codes is that the maximum deflection of floor systems shall not exceed 1/360 of the span. This standard bears no particular relationship to human tolerance,

but was established in the days when hard finish plaster was used upon the ceiling below and the deflection necessarily had to be reduced to the point where the plaster would not crack. With modern plasters and other modern ceiling materials this standard is no longer necessary, but it stays with us as a handicap through inertia. The deflection standard should be based upon safe optimum comfort rather than dogma inherited from the past.

The future will bring able competitors into the home manufacturing field. Through this competition the customer will be less likely to rationalize and accept defects in his home as being inevitable. Those companies which develop a team for ably producing and marketing a constantly improved home at lower prices will be the future blue chip companies of the manufactured home business. Those in the research laboratories have a very important position on that team. It is highly improbable that some miracle material or system will provide a substitute for the hard careful work of gradual development. This new undertaking needs your cooperation and in the end will justify that cooperation.

Discussion

Mr. M. E. Dunlap (U. S. Forest Products Laboratory): In the section of Mr. Farrier's paper dealing with moisture barriers, he mentions the difficulty of obtaining good barriers. It is probably true that many papers supplied to support thermal insulation are not adequate moisture barriers. However, good barriers are available, and if they are properly installed they will effectively stop the movement of moisture into wall spaces. In some cases coated paper-backed sections of insulation are simply dropped into wall spaces without sealing the edges. Water vapor can then move around the barrier and lodge on the cold side of the panel.

Mr. Armin Elmendorf (The Elmendorf Corporation): When we speak of engineering problems in the design of wood prefabricated or manufactured homes, we generally have in mind the determination of the size and shape of structural members that should be used. Using this definition, it would appear that most of the problems involved in the design of prefabricated homes are both new and old. They are new in the sense that we are beginning to realize that some of the forces acting on structural members can now be estimated and, on the basis of the assumptions made, the size of members can be computed. In this way, we can determine the depth and cross sectional area of stressed roof members which will be of sufficient size to resist roof loads without introducing excessive deflections. This can be done for the stressed-skin construction, as well as for conventional framing. The same is possible for the wall framing. Tests can also be made to determine the resistance to racking. Having determined the deflections that can be expected in certain roof or wall constructions and the maximum safe loads, we have in substance answered the basic engineering problems.

Only too frequently, manufacturers who start out to produce factory-built houses assume that some ingenious device which they may have worked out for fastening together wall and roof panels, combined with their knowledge of stresses and size of structural members to use, is all that is necessary. They soon learn, but only after substantial losses have occurred, that the subject is extremely complex and that many problems which appear to be soluble by engineering methods turn out to lie outside of the engineer's field. The engineer may be able to compute the size of framing members and test the wall panels for stiffness and strength and arrive at an answer, but when attempts are made to market a strictly engineered design, manufacturers are frequently confronted with customer resistance that makes merchandising very difficult. For example, a well engineered job may call for wall panels only two inches thick, but the layman purchaser views such thin walls with considerable misgiving and no rational approach can allay his fears. The engineer and the architect may both come to the conclusion that a flat roof of a certain thickness and construction fulfills all structural requirements, but the customer who has all his life seen only pitched roofs cannot be convinced to live under such a roof. The engineer alone cannot solve the problems as these are seen by the customer.

Some problems heretofore answered by the architect and engineer on the basis of past experience have now reached the point where precedent can no longer give a reliable answer. For example, a wall panel, if it is completely

factory-built, must not only provide sufficient strength and stiffness but it must also be impervious to the weather on the outside and impervious to vapor penetration on the inside. It must provide adequate insulation. Having fulfilled each of these requirements, is the designer sure that his construction is sound and safe? Unfortunately, imperviousness to weather also generally means imperviousness to vapor penetration; and vapor barriers on the room side are seldom complete vapor barriers. Some insulation, as well as the wood framing and wallboards used, are hygroscopic and when the outside of the house is exposed to the hot sun there may be a temperature difference between the outside and inside panels as great as 50°. Likewise, in mid-winter there may be 50° temperature difference between the inside and outside surfaces in the opposite direction. Such temperature differences cause moisture migration and differences in vapor pressure that may lead to serious condensation troubles. The problem is very complex and all of the information the physicist possesses must be brought into the picture. Tests can only be made on full-sized structures and even then, when such tests are made in a Climatometer, they are not always conclusive. In other words, complete confidence cannot be placed in engineering computations and a reliable technique for testing has still to be evolved.

While the engineer's contribution should not be minimized, it should always be borne in mind that the engineer's answers may not be the answers that will lead to commercial success.

Mr. Charles S. Walters (University of Illinois Agricultural Experiment Station): It seems to me that a most important problem, which Mr. Farrier has not mentioned in his paper, concerns the prevention of decay in homes. Tighter construction and use of moisture barriers and insulation may result in an improved environment for wood-rotting fungi. Since the homes are shipped to areas having widely varying climates and manufacturers are "very sensitive toward malfunctions in even a few of their products," it appears that the use of wood preservatives in the manufacture of prefabricated houses might be desirable. The economics of treating as well as methods and equipment for treating individual parts or entire subassemblies offer many problems.

Professors R. R. Hirt and J. L. Lowe, New York State College of Forestry, have reported in the October 1945 issue of the *Journal of Forestry* how quickly decay developed in housing as a result of using unseasoned lumber and modern construction methods. They suggested that the postwar market make available well seasoned and treated lumber for modern house construction. The mechanics of treating appear to be more easily adapted to prefabricated construction than to conventional building. Decay prevention should be of interest to the prospective purchaser and would be a choice point for discussion by the advertiser and salesmen.

Developments in the Postwar Packaging Field

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THE subject which has been assigned me for discussion at this time is a broad topic indeed. Today the manufacture of Packaging Materials alone is at least a five billion dollar annual business, and probably, if the facts were more readily obtainable, would be found to be a seven or eight billion dollar business (1).

Packaging Helps Us Live!

Of course if you stop to think about it a minute, there is every reason for "Packaging" to be so important! What plays a more vital though unsuspected part in our daily lives, as well as in the daily existence of American commerce and industry, than "Packaging"? . . ."Packaging" helps us live! . . . It is the shepherd of our subsistence for it delivers our personal necessities from furniture to food, safely, economically, and attractively. . . . And if we become ill (and I hope that we seldom do!) "Packaging" in some of its many forms is on duty to guard the purity and freshness of the life-giving medicines which restore well-being. Thus can "Packaging" be said to be an "accessory to life".

Postwar Developments in Packaging Field Classified

What are the most important postwar developments in the packaging field you ask? Well, in order that you might have the benefit of much more informed opinion than my own, I took the liberty of asking a group of commercial and industrial executives that very question. The time allotted me for this presentation does not permit detailed analysis of the results of this poll. Suffice it to say that there was divided opinion in the answers to my question, and quite naturally, some of it was pretty violent. These divided opinions as to what developments in the postwar packaging field are most important fall into two classes. Class number one covers those who think that the most important postwar packaging developments are in the consumer packaging materials field. Class number two covers those who think that these developments are in the industrial packaging field, the field of the functional or protective package, the field of the shipping package. But the most startling thing about this poll was the revelation of an almost complete unanimity of opinion on a third point which transcends developments in both consumer and industrial packaging fields. This third fact deemed so important a development is the opinion that package engineering has emerged as a full fledged business science and profession (2). It is this point, therefore, which I shall consider first, and then, time permitting, I shall review briefly what appear to be the most important developments in the consumer and protective packaging field as indicated in the answers to my poll.

Development of "Scientific Packaging"

I am sure that you are well aware of the fact that for many years some of our leading commercial and industrial organizations have maintained staffs of specialists whom they have classified as packaging engineers. In connection with these packaging divisions, many of these companies have established testing laboratories wherein package designs and materials have been subjected to certain standard tests designed to indicate the merit of a particular type of specification. Organizations like International Harvester, Sears Roebuck, Western Electric, General Electric, Eastman Kodak, General Motors, Ford Motor Company, Montgomery Ward, Owens–Illinois Glass Co., to name a few, long ago recognized the value of a scientific approach to the solution of their packaging problems.

Today this "scientific approach" is even more important. The "pressure" of business activity is greater, competition is keener, production problems, the intricacies of modern warehousing, transportation and distribution are more complex and result in greater hazards to all forms of packaged goods. In fact, you have undoubtedly heard all about the tremendous economic waste which accrues annually to American business through terrifically high loss and damage complaints.

In the early days of the profession, the packaging engineer had a less complex job. He performed it well, and his responsibilities have grown to the point where today his duties occupy an important and preeminent place in the management pattern (3). So it is logical that you as researchers should be interested in packaging development, and it is equally logical that the emergence of package engineering, of planned package design and product protection, as a full fledged business science be the most important of all developments, both in the consumer and industrial postwar packaging fields.

Present Evidences of Packaging Importance

We in the Industrial Packaging Engineers Association can bear witness to the soundness of this opinion, because our membership roster has tripled in the past two years. We have further evidence of the importance of packaging today from the fact that just a few weeks ago 115 executives, representatives of American business, journeyed to Detroit from all parts of the country to sit as students in I. P. E. A. A.'s week long Packaging and Material Handling Institute, which was conducted in cooperation with Detroit's Wayne University. Almost every day our mail brings a request from some company for aid in employment of competent packaging personnel. The railroads, the large mercantile organizations, the automotive industry, everyone is on the "bandwagon" for better packaging. Packaging "know-how" is being formalized in many educational institutions, and today as never before the packaging engineer and his colleagues in the testing laboratories are able to work effectively toward better packaging, better product presentation, better product protection, better shipping, better handling.

But lest you think that I am completely full of "propaganda" for the professions which I am so privileged to represent, let us now examine briefly the other principal developments in the postwar packaging field.

Other Important Packaging Developments Are Functional

There was some difference of opinion, as I mentioned previously, as to which developments are most important—those in the consumer packaging field, or those in the protective packaging field. Actually for our purpose the difference isn't too serious because basically the important developments in both phases of the field are primarily functional; in other words, they are concerned with performance, protection or preservation.

Consumer Packaging Developments

In the consumer field, opinion in the poll was that postwar developments in food packaging are most important. Here the consensus is that the introduction of new types and combinations of flexible packaging materials, such as aluminum foils and the wood cellulose films (cellophane, etc.) the rubber hydrochloride films (pliofilm) and the polyvinyl films merit your attention. And don't forget the new treatments of long known materials, such as sulphite paper, box and linerboards which do much for the package, even making it fungus resistant. You may already have seen evidences of the "new look" in postwar food packaging, because now at your grocers you can buy such things as bacon vacuum packed in flexible materials, oleomargarine in a rubber hydrochloride bag (pliofilm) which you can mold and color in your hands without touching the product itself, dill pickles in a brine-filled bag, and many other evidences too numerous to mention. If you are further interested, I recommend you read the talk on "Postwar Developments in Food Packaging", (4) prepared by Mr. A. V. Grundy, Chief, Quartermaster Food and Container Institute, Chicago, and delivered before I. P. E. A. A.'s Wayne University Institute.

Industrial Packaging Developments

In the industrial or protective packaging field, dealing primarily with materials which are forest products derivatives, there are also

many improvements worthy of your attention. Again, they are technical or functional, all of them enabling the shipping package, which is scientifically designed, to perform its tasks better, utilizing in many cases materials hitherto regarded as unsuitable to packaging material manufacture.

My opinion poll in the field of the industrial package points particularly to improvements in the manufacture of fibreboard boxes and wooden containers whose improved performance features have been achieved in a large measure through the use of newly developed adhesives of the phenolic and urea type, which have enabled these boxmakers to manufacture water-resistant containers now in increased demand for export shipments. Also through the use of improved adhesives, coupled with high-frequency bonding technique, we now find at least one of the large manufacturers of wooden boxes and crates using a previously unsuitable veneer stock and combining it with kraft paper to make a laminated box material which is now in wide demand.

For a review of technical developments in the paper shipping container field, I refer you to a very fine talk given by Mr. W. F. Gillespie of the Mill Division of the Gaylord Container Company, and delivered before I. P. E. A. A.'s Second Annual Packaging and Material Handling Forum last spring here in Chicago. This paper is entitled "New Materials for Better Boxes" (5), and in it Mr. Gillespie outlines in some detail improvements in box-making materials which are the result of the use of previously unused hardwoods, such as gum and oak in the south and aspen in conjunction with cottonwood and birch in the north. More widespread use of hardwood species, Mr. Gillespie points out, in combination with softer woods means better boxboard, better fiber formation and strength, and better color.

The older forms of forest product derivative industrial package, the wooden box and crate, the barrel, protective wrapping papers, have all been streamlined, though packaging materials in general continue in short supply, and the technical improvements may not always be uniform. The wirebound box and the cleated fibreboard container have been improved in design and construction too, and are now adaptable to many new products. Other protective packaging materials, such as excelsior and macerated paper pads and blankets, wood cellulose pads and wadding, are being used to complement other protective packaging media.

And don't forget a war-time packaging development which has won a very definite place in the postwar packaging field, namely, scientific product cleaning and anti-corrosion treatment. Many thousands of manufacturers of finished or semi-finished products, subject to corrosion, have found that it pays to use rust preventive coatings and films. The wartime moisture preventive treatments have earned a definite postwar place in packaging. Yes, packaging is "big business" in the best sense of the words, and the foregoing has been a very sketchy treatment of a broad subject.

In closing, I would like to call your attention to one phase of packaging activity which has assumed new importance in this changing business world of ours, that is the importance of scientific package design as related to effective material handling. This is not strictly a packaging subject and so I have not touched upon it here today. Nevertheless, material handling is a topic worthy of your attention, for planned material handling can result in tremendous production economies which will repay your interest in the subject hundredfold.

In conclusion, permit me to leave this thought with you. If you have a packaging problem get yourself a packaging engineer. He will design your package, test it in the laboratory and in the field, and keep you way ahead in "making profits from problems through scientific product protection".

To those of you who are interested in the advancement of forest products in packaging, take heart! At the outset of this talk I mentioned the fact that the manufacture of packaging materials amounts annually to a value in excess of five billion dollars. Of this figure I estimate that probably 70 percent is attributable to materials which are technically forest products. Many of them have come a long way from Longfellow's "Forest Primeval" and would seem to be more definitely allied with Sandburg's "City of Smoke and Steel", but the development of today's packaging materials has been a fascinating growth and the field is still young—long may it live!

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Discussion

Mr. Don L. Quinn (The Don L. Quinn Container and Materials Testing Laboratory): From our viewpoint, one of the most important developments in the postwar packaging field is the growing appreciation of the value of having all container quality merits judged by their performance, both in service and in testing. This applies not only to the individual containers, but also to the packaged items as offered to the freight carriers for transportation. Probably the outstanding recognition of the value of standards based on performance is that of the Bureau of Explosives. Every package standard in the Bureau of Explosives regulations has some specification for the materials, but every one of them, regardless of whether the container is of metal, wood or fibreboard, has a performance standard, and that performance standard is recognized as being the effective requirement.

A representative of the Bureau of Explosives told me within the past few days that the Bureau is proposing to rewrite all of its container specifications in which they will minimize the materials specifications and increase the standards based on performance. This so important precedent is influencing carriers, shippers and container manufacturers in their approach to the containers for non-dangerous articles. To my way of thinking, this is the most important development in the postwar packaging field.

FOREST PRODUCTS RESEARCH SOCIETY

Something New in Functional Furniture

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This paper describes the inception, development, and construction of a new type of modern functional furniture, known as Module, which was first placed on the market in July 1946. It also relates its advantages and disadvantages to customers, stores and the manufacturer, compared with conventional furniture, and cites some of the difficulties and problems incident to its production and sale.

Module Furniture

FURNITURE is one of the oldest and largest uses of forest products. There has been some increase in the use of aluminum, steel and plastics in its manufacture, but wood still retains and no doubt will continue to retain its dominant and almost exclusive position as furniture's raw material.

Although the Early American and traditional 18th Century styles have persisted and continue in good demand, making up about 55 percent of the total, modern furniture has shown considerable growth in recent years. And in the past several years there has appeared on the market, mainly in modern design, what is called "functional" furniture, the name coming from its interchangeability and the fact that it can be added to and assembled in different ways.

The subject of this paper is the new and particular type of functional furniture known as Module, the name deriving from the fact that all units of the furniture are designed to a modulus of six inches. Module furniture might also be defined as a new type of modern mahogany bedroom, dining room, and living room sectional furniture which can be put together in innumerable combinations to fit almost any taste or need. Its outstanding attribute is its flexibility, that is, being able to use the different basic cases and parts like building blocks, to secure any desired piece or combination of pieces. (See Figure 1.)

Inception of the Product

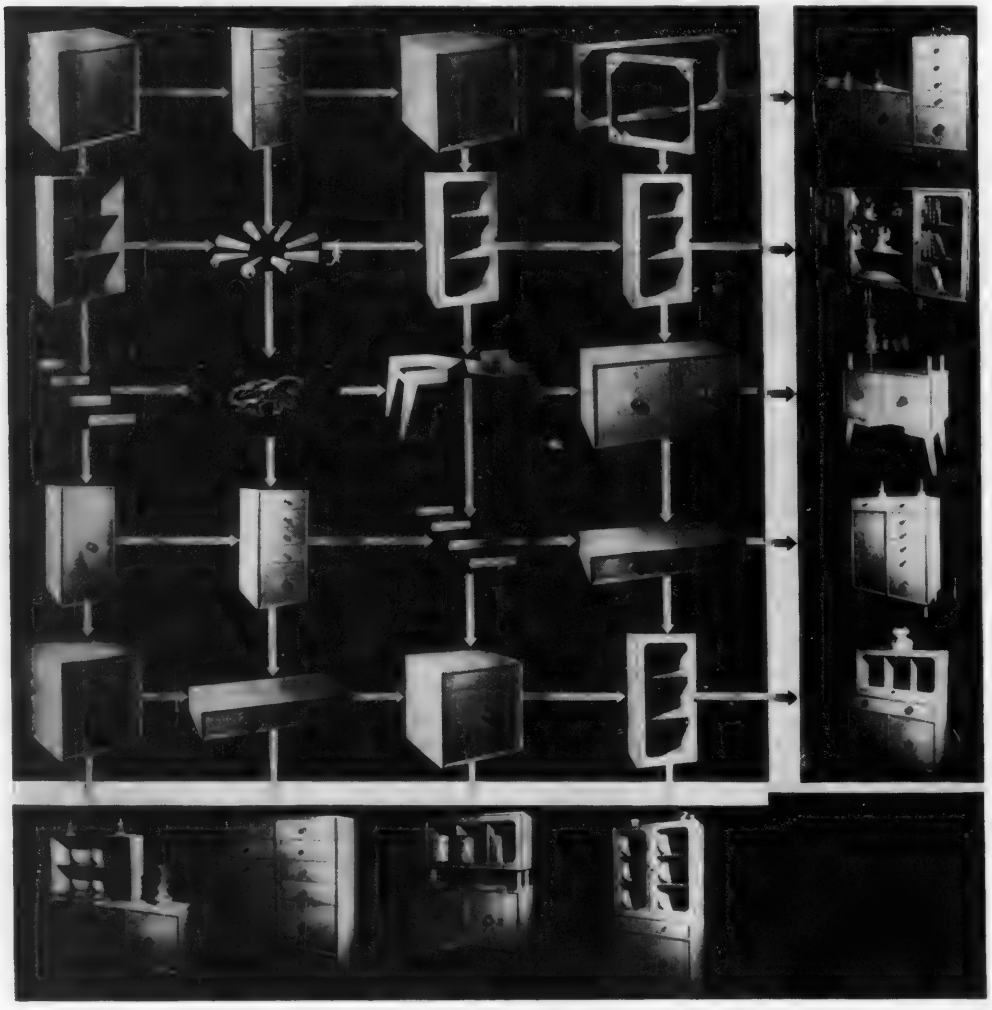
Module is the joint development of its manufacturer, The Mengel Company of Louisville, Kentucky, and its originator and designer, Morris Sanders of New York. The Mengel Company, now in its 70th year, is one of the country's largest woodworking manufacturers.

Its products include mahogany and southern hardwood lumber, plywood and veneers, doors, wooden and corrugated paper boxes, furniture and other products. Mr. Sanders, a native of Arkansas, is a New York architect and designer and a graduate of Andover and Yale. He spent nine years, and The Mengel Company two years, in developing this furniture system. As something new in a forest-products article, as well as in functional furniture, it may interest you gentlemen to learn of some of the problems connected with its development, manufacture and sale.

Mr. Sanders tells us that his conception of Module dates back to his college days at Yale, where, upon passing and repassing a gateway inscribed with the name of Eli Whitney, he dreamed of extending to furniture Whitney's concept of the interchangeable manufactured part. The problem he set up for himself years later was to figure out the most flexible case goods system possible—something that could be used with any type of front in any position in any room. He had in mind a "personalized" furniture, furniture that would permit the expression of individuality and that would solve the problem of built-in bookshelves and storage chests.

Problems of Development

It was necessary to determine what basic parts to use, their sizes, how to connect them, and what woods and finish would be most suitable and salable.



—Courtesy Life Magazine.

Fig. 1.—Acrostic, illustrating different pieces of furniture made by connecting 13 basic Module parts in different ways.

Being an architect, it was natural for Sanders to base the dimensions of the cases and parts on a modulus. He experimented with four inches, the accepted building-trade modulus, but it resulted in cases either too small or too large, and six inches was finally decided upon. This provided a case size of 36 by 18 by 18 inches, instead of the larger size of 40 by 20 by 20 inches or the smaller size of 32 by 16 by 16 inches. It was necessary to make the cases easily joinable to each other, in either a vertical or horizontal position, and to different design legs and bases. To accomplish this, holes were at first bored all over the case. This gave too much the appearance of a Swiss cheese and the number of holes has since been reduced to six on the top and bottom and four on each end of a 36 by 18 by 18 inch case.

As to the kind of wood and case construction, there were several possibilities. For solid-case construction, western pine would have been least likely to warp and would also be

low in cost, but it was discarded because of questions about its salability. Oak plywood would have given a good color for modern furniture, but because of the prestige of mahogany, its proven acceptability in modern furniture in a light or bleached finish, and the fact that the manufacturer enjoyed certain competitive advantages in mahogany, ¾-inch mahogany panels were decided upon. Bleached mahogany finishes are quite frequently used in modern furniture but because of the manufacturing problem of bleaching, particularly in large volume production, and its susceptibility to "bleed" or change color, a light or "natural" mahogany finish was developed. This finish is a new type of synthetic varnish made from urea alkyd resins, and has the pinkish hue characteristic of freshly sliced mahogany veneer.

Considerable experimentation was carried on with methods of constructing the individual

Fig. 2.—Inside view of case, showing wooden drawer guides which are fitted into drawer guide holes in the case by means of steel pins. Note also coin is only tool required to insert connector.

case, that is, of joining together the sides and ends of a case. Mitre joints are used and, at first, a butterfly spline was driven into each corner for nearly the full depth of the case to lock the mitred corners together. However, this type of joint was abandoned in favor of a lock-type mitre similar to that used on cedar chests.

Another problem of development was how to have each and every basic case adaptable for drawers, shelves and grille, and solid and sliding glass doors, whether in horizontal or vertical position. Also, in keeping with ultimate flexibility, there was the question of how to design the case interiors so that a store or a customer could remove and replace drawers with doors or shelves. This feature was accomplished by an ingenious pre-boring of sets of small holes in the interiors of all cases. One set of these holes accommodates the drawer guides which have steel pins, another the shelf channels and another the door hinges. (See Figure 2.)

Description of the Completed Product

Having defined the original conception of Module functional furniture and some of the problems incident to its development, let us now examine and describe the completed product in greater detail, mention the plan of distribution of the furniture and the acceptance it has received, and, last but not least, enumerate some of the troubles being experienced in both its manufacture and sale.

The furniture consists of six basic cases, five bases, solid and grille doors, drawers and shelves. From these can be made breakfronts, chests, commodes, bookcases, and even an entire wall or partition. (See Figure 3.) Module also includes beds, mirrors, benches, occasional tables, dining tables and chairs. The

Fig. 3.—Large Module wall assembly and cocktail table. The large assembly is constructed of 15 units of the same basic case, but with different "faces," and three units of the same base. The cocktail table is constructed of one case and a base.

six cases measure from 18 to 36 inches wide or long, 12 to 18 inches deep, and six to 24 inches high and can be used either horizontally or vertically, alone or joined together. Most of the cases can be fitted either with wide or narrow drawers, shelves, solid doors, sliding glass doors, or grille doors.

Legs, bases, and wooden rods called "spacer-bracers" can be connected with the units to achieve almost any standard furniture purpose as well as many new ones. Cases can be assembled in compression or in tension, they can sit one upon the other or next to each other, be cantilevered, or hung from wall, ceiling or from other pieces; they can stand independent and alone in the traditional manner of furniture—of chests, desks, breakfronts, vanities, consoles, credenzas, cabinets, or bureaus, or can be solidly constructed into built-in and semi built-in assemblies. Besides this, the cases can be brought together in such a manner as to create "free-space," that is, by surrounding space with cases or by spanning it. Module can also be arranged back to back to act architecturally as a room divider.

Tops, ends and bottoms are ¾-inch five-ply panels, banded on the front edges by strips of solid mahogany. The outside faces are sliced quartered and the inside faces flat-cut African mahogany. The cores are soft-textured Appalachian poplar and the cross bands straight-grained poplar and gum.

Drawer fronts, solid doors and shelves, like the tops, ends and bottoms are ¾-inch five-ply solid-core panels with African mahogany faces. Frames for the grille doors and the legs and base parts are solid mahogany. Drawer sides are oak and drawer guides beech or hard maple. Back panels are ¼-inch three-ply African mahogany with flat-cut face and gum back.

Jointure of Case Sides and Ends

As previously mentioned, tops, bottoms and ends are joined by a lock-type mitre joint, similar to that used on cedar chests. To prevent these joints from showing in the outside edges, a cylindrical hole is bored in each of the four outside corners and a mahogany dowel inserted. This gives the appearance of a peg, which is common usage in Early American designs. Because of the lock-type joint, the case cannot be assembled as one would an ordinary box, by clamping and gluing together the sides and ends. Instead, after applying glue to the special mitred corners, the box parallelogram is assembled edgewise by sliding the ends into the sides. Since it is not known at the time of assembly whether the basic case will be used in vertical or horizontal position or with or without drawers or doors, there is no bottom, that is, all exposed surfaces of the case must be finished and the inside must also be finished. The backs are really the only unexposed part and these are ¼-inch plywood set in a rabbett in the back edges of the sides and ends.

Glue and Gluing

All plywood used in the manufacture of Module is glued up with synthetic resin glue. This applies to edge joining the veneer faces and cross bands, as well as to edge gluing the lumber cores. The faces, backs, and cross bands are edge glued in a tapeless splicer at an electric heat of about 350 degrees Fahrenheit. The panels are laid up in both hot plate and cold presses under a pressure of from 175 to 200 pounds per square inch. Temperature of the hot plate press is about 250 degrees Fahrenheit.

Assembly of the sides and ends of the case units is made in extremely accurate and complicated jigs, operated under pneumatic pressure. As in the plywood, synthetic resin glue is used, but in this operation the glue is set electronically in 20 to 30 seconds as compared with the six to eight hours ordinarily required. Another electronic gluing operation is the glue blocks on the bottom of the drawers.

Means of Connecting Cases

Mention has been made of the high degree of flexibility of Module and the fact that different pieces of furniture can be constructed for individual taste and requirements by arranging and joining together the various basic cases and parts in different designs. The means of attachment is a double-headed threaded aluminum connector with a male and female section. (See Figure 4.) All cases are pre-bored at the factory with holes to accommodate the connectors, which are shipped to stores in bulk. The number 100 case for example, which measures 36 by 18 by 18 inches, is bored with 20 connector holes, six in the top and bottom and four in each end. The $\frac{9}{10}$-inch holes are

Fig. 4.—The two parts of the aluminum Module connector.

spaced two inches in from the outside edges of each face and have a ¾-inch diameter and $\frac{3}{16}$-inch deep counter bore at each end, so the heads of the connector when inserted will fit flush with the outside and inside case surfaces.

Drawer a Special Feature

In building a piece of furniture by connecting several basic units, some holes are nearly always left exposed. To fill these holes, stores are supplied with two-piece friction fittings, plastic plugs similar in shape to the connectors and of a color which blends nicely with the natural mahogany finish.

The drawer is a patented one of the manufacturer's own development. Its advantages are a molded plywood bottom for easy dusting, and drawer sides which operate in a manner similar to filing cabinet drawers to provide easy sliding. (See Figure 5.) The U-shaped drawer bottoms are set and glued into grooves in the drawer fronts and backs. The side or vertical parts of the molded bottoms are glued to a narrow solid-oak drawer side. A groove or channel in the outside face of this drawer side engages and slides upon a horizontal-cleat drawer guide, which is attached by steel pins to the case ends or sides. As the solid drawer sides are only about two inches wide across the grain, the tendency to expand and contract and cause sticking is minimized, and from this feature derives the name Permaslide drawer.

Sale and Distribution

The furniture is sold by the manufacturer direct to department and furniture stores in parts and subassemblies. The store warehouse unpacks and connects these units into whatever piece of furniture is desired by the customer. Large assemblies are delivered by the store in sections and the final assembly made in the home. The furniture lends itself to unusual display and these displays can be easily rearranged.

Sale of Module was begun by four department stores in the New York area in July 1946. It has sold well and received an unusual amount of editorial comment and publicity in nearly 100 newspapers and magazines, including three pages in *Life* magazine. Its individual customers range from Henry Kaiser and Henry Ford to Carole Landis and "Sugar Chile" Robinson, and the business concerns to whom it has appealed vary from the J. Walter Thompson Advertising Agency to the Rexall Drug Co. Because of the experimental nature of the product and the specialized selling required by the stores, sale of Module has been restricted thus far to 43 stores in 41 cities. This has provided an opportunity for both the stores and the manufacturer to study and improve the product and methods of selling it.

Fig. 5.—Module drawer, showing method of suspension for easy sliding, and rounded corners in molded plywood bottom for easy dusting.

Advantages and Disadvantages

The customer secures distinctive, high quality, attractive-looking furniture that is completely flexible, that is, it can be assembled to any length or height, and in any arrangement, to fit the customer's specialized need. For this flexibility the customer pays a higher price than for the equivalent in regular furniture, providing the equivalent can be secured in the desired style, arrangement and size, but a lower price than for built-in furniture.

For the store, Module increases sales, builds repeat business, develops store traffic, improves display, helps sell other home furnishings, establishes the store as a leader and gives it a product with which to combat built-in furniture competition. Against these advantages, Module is more difficult and expensive for the store to warehouse, sell and deliver.

Although Module accounts for only about one million of the manufacturer's eight million dollars furniture sales, it has created prestige and provided national publicity unequaled in the industry. Although a standardized article, it requires much greater accuracy and is more costly to produce than conventional furniture of equivalent cubage. Other difficulties experienced are variance in finish caused mainly by a variance of grain and porosity in the mahogany veneer, warping of doors, a tendency for the 36-inch case sides to bow in, and at times difficulty in assembly caused by even a slight variation in the boring of the connector holes.

Problems and their solutions will continue and it may well be that the future Module product may not be easily recognizable as a descendent of the present one. Someone has been kind enough to say that Module is the greatest advancement in furniture since the days of Chippendale. If this be partially true and its designer and manufacturer in a modest way have added something to the contribution that forest products make to the comfort and enjoyment of American homes, I am sure the effort has been justified.

FOREST PRODUCTS RESEARCH SOCIETY

Postwar Developments in Woodworking Glues

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The postwar developments in adhesives for woodworking have followed in the direction of improving operating characteristics or availability and of decreasing glue-line costs, rather than in the direction of increasing the durability of the glue joints. Among the developments toward improving operating characteristics or increasing availability were the polyvinyl-resin emulsion glues; the separate-application, resorcinol-resin glues; synthetic resin glues formulated for use with high-frequency circuits; further changes in the formulation of separate-application, urea-resin glues; and the development of a modified blood-albumin glue. The efforts to reduce glue-line costs included investigations on the extension of phenol-resin glues with corn gluten, with soybean and linseed meal, and with Douglas-fir bark; the extension of resorcinol-resin glues with corn gluten; and continued investigations on the effects of extending urea-resin glues with flour.

Introduction

BY THE end of World War II, the woodworker had available a wide choice of glues that included the older animal, starch, casein, and seed-meal glues, together with a variety of newer adhesives of the synthetic-resin types. In the phenol and melamine types, adhesives were available that permitted convenient manufacturing of highly serviceable plywood by hot pressing. The resorcinol glues enabled the manufacturer to produce durable assembly joints at room temperatures and, by the use of the intermediate-temperature-setting phenol- and melamine-resins and phenol-resorcinol-resin blends, laminated members that were highly durable could be produced. For the first time in woodworking history the manufacturer, by a proper choice of glues, could produce in nearly all glued wood products joints that were as durable as the wood itself.

Since glues of durability adequate for most purposes were generally available, the postwar developments in adhesives followed in the directions of improving the operating characteristics or availability and of decreasing the glue line costs rather than of increasing the durability.

Among the developments toward improving operating characteristics or increasing availability were the polyvinyl-resin emulsion glues, the separate-application resorcinol-resin glues, synthetic resins formulated for use with high-frequency circuits, further changes in the formulation of separate-application urea-resin glues, and development of modified blood-albumin glues. The efforts to reduce glue-line costs included investigations on the extension of phenol-resin glues with corn gluten, with soybean and linseed meal, and with Douglas-fir bark; the extension of resorcinol-resin glues with corn gluten; and continued investigations on the effects of extending urea-resin glues with flour.

[1] Maintained at Madison, Wisconsin, in cooperation with the University of Wisconsin.

Developments Affecting Operating Characteristics and Availability

Separate-application Urea-resin Glues

The principle of separate application, or applying one component of an adhesive to one surface and another part or component to the other surface, is not new. It is reported that a German patent (DRP 66202) issued in 1892 described a process of applying an ammoniacal solution of casein on the surfaces to be glued and later coating the surfaces with milk of lime just before assembling and pressing. The practice of applying animal glue on one surface and a formalin solution on the other has been recognized for a number of years. Some of the first room-temperature-setting urea-resin glues used in this country were of the separate-application type.

The separate-application urea-resin glues were apparently more favorably received and more commonly used in Europe than in the United States. During World War II, glues of this type were developed in England that

apparently met British specification requirements for aircraft purposes[2] and that permitted pressure periods as short as 1¾ hours at 70° F. In Germany, likewise, it appeared that the use of separate-application hardeners was not uncommon. In this country, advances in separate-application urea-resin glues were apparently hampered by a lack of willingness to accept the results of separate-application technique as fully equal to those obtainable with one-part glues. The hesitancy was caused, in part, by experiences with the earlier formulations that raised considerable question of obtaining joints of satisfactory uniformity and, in part, by lack of sufficient and consistent data on the effect of the rapidly acting acid hardeners on the durability of the joints. Limited investigations made at the Forest Products Laboratory have indicated that such hardeners as oxalic acid, formic acid, phosphoric acid, and ammonium chloride, when applied separately on one of the surfaces, would cause rapid setting of urea-resin glues at room temperatures and produce joints of high dry strength and initial water resistance, but, in an accelerated durability test, the joints proved less resistant than those made with the better one-part urea-resin glues. On the other hand, joints made in yellow birch, yellow-poplar, and Douglas-fir plywood with some of the early separate-application formulations and subjected to weathering tests appeared to be essentially equal in durability to similar joints made with one-part urea-resin glues offered at the same period.

The continued demand for faster curing appears likely to result in further advances in separate-application urea-resin formulation. To promote wider acceptance, it seems that conclusive experimental evidence should be developed demonstrating the uniformity and durability of joints made with separate-application formulas.

Separate-application Resorcinol-resin Glues

Resulting from the same basic demand for glues that would set rapidly at room temperatures, separate-application glues based on resorcinol resins have been recently offered to the woodworking industry.

Data for adequate evaluation of these glues appear to be lacking at the present time. Limited tests have indicated that joints in maple developed sufficient strength in 20 to 30 minutes at room temperatures to permit release of gluing pressure. When the joints were tested promptly after these short pressure periods, they possessed only a part of their final dry strength and water resistance, but tests at successive periods after release of pressure indicated a gradual increase in strength for several days.

From short-term accelerated-exposure tests, it appeared that longer pressure periods would be required if maximum resistance to delamination of the joints in the denser species was required. Results of adequate durability tests and detailed information on operating techniques, however, do not appear to be available at this time.

Adequate evaluation will require information on uniformity of joint quality, on effect of formulation on initial strength and durability, and on the relation between the pressure period and durability. More information is also desirable on the effect of operating details, such as the effect of species, of moisture content and temperature of stock, and of assembly periods.

To insure a place in competition with adhesives now available, it seems that the separate-application resorcinol resins must prove capable of producing uniformly strong and durable joints more economically and more conveniently than joints of high quality can now be produced by the use of high-frequency heating or by the use of long pressure periods.

Glues for High-frequency Heating

The use of high-frequency circuits for heating resin glue lines offers a method of effecting a very marked reduction in the pressure period required and, in heavy laminated members, provides a method of curing resin glue joints that by other methods of heating might require impractically long pressure periods. In the high-frequency field, the curing of the resin glue joints is accomplished most rapidly, of course, if the electrodes are so arranged that the field is parallel to the glue joints. When so arranged, however, difficulties with arcing and burning become more pronounced. Several

[2] Bulletin 25. Aero Research Technical Notes, Aero Research Ltd., Duxford, Cambridge, England.

resin glues have been offered recently that are formulated to reduce difficulties with arcing in high-frequency fields.

Very little technical literature has appeared dealing with the causes and methods of prevention of arcing across glue lines in high-frequency fields. Apparently the difficulties encountered have often been remedied by changes in formulation, by substitution of other glues, or by adjustments in equipment as demanded by the individual operation.

From limited observations made on uncovered layers of different glues on wood heated in a high-frequency field parallel to the plane of the glue line, several different glues have been classified[3] as to arcing tendencies as follows:

Very bad
- Alkaline high-temperature-setting phenol-resin

Bad
- Intermediate - temperature - setting phenol resins
- Casein
- Soybean

Good
- Urea-resins
- Resorcinol-resins

Very good
- Melamine-resins
- Acid phenol-resins

Under the conditions of the experiment no arcing occurred with the melamine, acid-phenol, urea, or resorcinol-resin glues. With the soybean, casein, and intermediate-temperature-setting phenol-resin glues some arcing and carbonization occurred, after which the action ceased. With the alkaline high-temperature-setting phenol-resin glues, brown carbonized streaks appeared perpendicular to the field soon after the glue began to boil, then points in the streaks arced forming deeply carbonized black paths parallel to the field, after which the wood burst into flames. Several high-temperature-setting phenol-resin glues varying in alkalinity were tried. The more alkaline the glue, the more quickly the brown perpendicular streaking and the black parallel paths appeared. From these very limited data the resorcinol-resin, urea-resin, melamine-resin, and acid phenol-resin glues do not appear impractical for use in high-frequency fields.

[3] Proceedings: Conference on Radio Frequency and Its Application in Gluing Wood, pgs. 49–51, H. D. Bruce. Univ. Wash. College of Forestry Bulletin No. 2 (Jan. 16, 1947).

Modified Blood Glues

Efforts, varying in intensity, to produce acceptable woodworking glues from blood albumin have been in progress for at least the last 30 years. During World War I, some plywood was made by hot pressing glues that were essentially mixtures of blood albumin, lime, and ammonium hydroxide. A paraformaldehyde-blood formulation developed at the Forest Products Laboratory proved capable of producing joints of moderate to high resistance when hot pressed.[4] The formula gained some acceptance in England, but it was not used to any important extent in this country. Blood albumin has been used in combination with phenol resin in the formulation of high-temperature-setting glues for the production of plywood.

One of the more recent commercial developments in the use of blood is the formulation of an intermediate-temperature-setting adhesive from a blood fraction. The results of very limited tests by the Forest Products Laboratory indicated that the glue was capable of producing reasonably strong joints in softwood species of low and intermediate density. In limited wetting and drying tests, the joints appeared reasonably resistant, but results of prolonged durability tests are not available and further development appears desirable if its use on hardwoods of high density is contemplated.

Polyvinyl-resin Emulsion Glues

General description. — The polyvinyl-resin emulsion was developed as a woodworking glue about 1945, when the supply of animal glue was insufficient to meet demands and a substitute was sought.

The polyvinyl emulsion was found to be quick setting like animal glue, easy to use, to have an indefinitely long working life, and to give an inconspicuous glue line that had very little dulling effect on cutting tools. For these reasons it soon gained rather wide-spread use.

[4] U. S. Patent 1,459,541.

The Forest Products Laboratory has examined 11 commercial polyvinyl-resin emulsion glues,[5] designated in this report by the letters A through K, to obtain information on their properties and characteristics.

The polyvinyl emulsions are milky liquids containing polyvinyl resins finely dispersed in water. The resin appears to be polyvinyl butyral, acetate, chloride, or mixtures in various proportions. Plasticizers, fillers, pigments, and other ingredients may be present in addition to the resin and water.

The polyvinyl glues are ordinarily used at room temperatures. The setting action takes place when the water of the glue diffuses into the wood, whereupon the emulsified resin coagulates. The coagulation appears to be partially reversible; the set resin absorbs water, softens, and at least partially redisperses, if it becomes wet. For this reason the current polyvinyl-resin emulsion glues have little water resistance.

The results of determinations of acidity, viscosity, and nonvolatile content are given in table 1. All the polyvinyl-resin emulsion glues were slightly acid, with pH values between 4.2 and 5.3, except one that was slightly alkaline. With one exception, the viscosities were between 3.0 and 16.6 poises, a range that does not differ greatly from other resin glues. The nonvolatile content varied considerably; four glues had nonvolatile contents varying from 31.7 to 34.5 percent, two from 41.6 to 47.7 percent, and seven from 50.0 to 58.6 percent.

Joints in birch plywood.—Plywood panels were prepared with each glue, by bonding together three plies of $\frac{1}{11}$-inch yellow birch veneer. In half of the studies the veneer contained 6 percent moisture at the time of gluing and in the other half, 12 percent.

The average results of the joint tests on the plywood specimens are given in table 1. Differences in joint strengths obtained on the plywood made from veneer at 6 percent moisture and at 12 percent moisture were usually small. The different glues varied considerably in dry joint-strength (columns 5 and 8 of table 1), varying from 198 pounds per square inch (zero pounds per square inch for a 30-minute pressing period) to 789 pounds per square inch. The average proportion of the failure that lay in the wood of the plywood specimens tested dry varied from zero to 94 percent. None of the glues showed much water resistance (columns 7 and 10 of table 1), although some of them showed moderate strength after one week in high relative humidity (columns 6 and 9).

Joints in maple blocks.—Block joints were prepared with each glue by bonding together two ¾- by 2½- by 12-inch pieces of hard maple of 6 percent moisture content. The average results are given in columns 11 to 15 of table 1.

Joints made with four of the polyvinyl glues tested above 2,800 pounds per square inch under all assembly conditions used. Six of the polyvinyl glues failed to produce joints testing as high as 2,800 pounds per square inch under any of the gluing conditions tried.

Effect of moisture changes on edge-glued joints.—Boards were prepared by edge-gluing together four 1- by 4- by 25-inch boards of hard maple. Four polyvinyl resin glues, an animal, and a casein glue were used. The moisture content of the wood at the time of gluing was approximately 6 percent. Two assemblies were prepared with each glue and each assembly was sawn to produce two panels each approximately 12 by 12 inches. From one of the panels prepared with each glue, block shear test specimens were cut to test the strength of the joints. The remaining panels were placed in laboratory exposures, one panel made with each glue in a room at 80° F. and 65 percent relative humidity, one in a room at 80° F. and 80 percent relative humidity, and one in a room at 80° F. and 90 percent relative humidity. They were kept in these exposures for one month; then all the panels were moved to a room at 80° F. and 30 percent relative humidity where they remained for one month. Table 2 presents the average results of the control strength tests and the observations made on the panels after exposure to the humidity cycles. Figure 1 shows the exposed panels after one of the cycles of exposure. These results again indicate the great range of behavior in the current polyvinyl-resin emulsion glues. None of the polyvinyl glues was the equal of the casein glue in this test. Under the greatest moisture change, the joints made with animal glue showed more

[5] Forest Products Laboratory Report No. R-1687 "Polyvinyl Resin Emulsion Woodworking Glues: A Study of Some of Their Properties." W. Z. Olson and H. D. Bruce (In press)

TABLE 1.—SHEAR STRENGTH OF JOINTS IN YELLOW BIRCH PLYWOOD SPECIMENS MADE WITH 11 DIFFERENT COMMERCIAL POLYVINYL-RESIN EMULSION GLUES

Glue symbol	pH of liquid glue	Viscosity[1]	Nonvolatile contents[2]	Shear strength of joints: Yellow birch plywood joints[3]: Veneer at 6 percent moisture: Tested dry[5]	Tested moist[6]	Tested wet[7]	Veneer at 12 percent moisture: Tested dry[5]	Tested moist[6]	Tested wet[7]	Hard maple block joints[4]: Gluing pressure 150 p.s.i.: Open assembly 10 minutes	Closed assembly 2 minutes	Closed assembly 10 minutes	Closed assembly 30 minutes	Gluing pressure 25 p.s.i. Closed assembly 2 minutes
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
		Poises	Percent											
A	4.8	8.2	55.9	[8]435–41	[8]387–17	[8]0–0	[8]419–48	[8]302–5	[8]0–0	[8]4,282–8	[8]4,359–8	[8]4,641–3	[8]4,809–2	[8]3,612–7
B	5.3	179.0	31.7	0–0	-----	----	0–0	-----	----	1,084–0	809–0	569–0	911–0	1,109–1
B	5.3	179.0	31.7	[9]568–31	[9]64–0	[9]0–0	[9]531–36	[9]73–0	[9]0–0	-----	-----	-----	-----	-----
C	4.3	12.2	52.1	458–11	96–0	40–0	459–5	118–0	40–0	324–0	322–0	353–0	242–0	472–0
D	4.2	11.8	57.5	330–11	332.6	40–0	308–4	297–10	40–0	2,657–1	2,658–0	2,506–1	2,646–0	-----
E	5.0	12.8	47.7	703–89	231–3	11–0	557–94	261–5	8–0	4,171–4	3,033–1	3,539–3	3,679–2	3,088–0
F	4.7	16.6	50.1	617–75	312–7	20–0	571–84	321–10	24–0	3,966–0	3,474–0	3,708–1	3,381–0	3,174–0
G	5.3	10.0	50.0	789–44	278–0	12–0	744–65	274–2	0–0	2,631–0	1,827–0	2,392–0	2,259–0	2,016–0
H	8.7	7.8	34.5	0–0	-----	----	0–0	-----	----	499–0	173–0	430–0	166–0	514–0
H	8.7	7.8	34.5	[9]198–0	[9]0–0	[9]0–0	224–0	[9]0–0	[9]0–0	-----	-----	-----	-----	-----
I	4.3	3.0	52.3	402–11	293–4	0–0	362–42	304–9	0–0	3,404–5	3,609–5	3,832–14	3,840–21	3,080–3
J	4.9	11–8	58.6	612–45	298–1	0–0	436–24	272–3	0–0	2,837–3	2,814–0	3,204–0	2,004–0	2,944–0
K	4.9	8.9	41.6	407–3	175–0	0–0	453–6	207–0	0–0	243–0	223–0	493–0	295–0	445–0

[1] Measued at 78° F.

[2] When dried in an oven at 220° F.

[3] Three-ply, 3/16 inch of 6 percent moisture content, pressed at 75° F. for 30 minutes under 150 pounds per square inch, except as noted for glues B and H in footnote 9.

[4] Two ¾-inch laminations of hard maple at 6 percent moisture content glued together at 75° F., held under the pressure indicated for 30 minutes.

[5] Tested dry after 1 week at 80° F. and 30 percent relative humidity.

[6] Tested moist after 1 week at 80° F. and 97 percent relative humidity.

[7] Tested wet after soaking in water for 48 hours at room temperature.

[8] The value before the dash is average shear strength in pounds per square inch; the value after the dash is average estimated wood failure in percent. Each plywood test value is the average for at least nine specimens; each block test valuse is the average for at least five specimens.

[9] Pressed for 224 hours.

TABLE 2.—EFFECT OF MOISTURE CHANGES ON EDGE JOINTS IN HARD MAPLE PANELS,[1] GLUED WITH FOUR POLYVINYL, ANIMAL AND CASEIN GLUES

Glue	Control shear test results	Delamination[2] at end of exposure cycle[3]		
		Exposed to air at 65–80, then to air at 30–80	Exposed to air at 80–80, then to air at 30–80	Exposed to air at 90–80, then to air at 30–80
A	[4]3103–68	0	0	6
G	2096–3	4	56	94
J	2809–3	0	14	12
K	623–0	63	100	100
Animal	2857–69	0	0	26
Casein	2735–92	0	0	0

[1] Each panel consisted of four maple boards glued together at the edges.
[2] The percentage of the total length of glue line exposed on both sides of the panel that was observed to be open. Each value represents observations on a single panel.
[3] The cycle consisted of 1 month in each condition (a total of 2 months for each cycle).
[4] The value before the dash is average shear strength in pounds per square inch; the value after the dash is average estimated wood failure in percent. Each value is an average of 15 specimens from 3 edge glue joints in 1 panel.

delamination than did the joints made with polyvinyl glues A and J. Glues G and K had little resistance in this construction to the delaminating stresses set up by the moisture changes.

The results of these tests conform to experiences with polyvinyl-resin glues in the furniture industry. In several examples of faulty joints in furniture parts received by the Forest Products Laboratory, the cause of joint failure

Fig. 1.—Edge joints in maple glued with polyvinyl-resin emulsion glues A, G, J, and K, an animal glue, and a casein glue after exposure for one month in a room at 80° F. and 80 percent relative humidity followed by one month in a room at 80° F. and 30 percent relative humidity.

appeared to be the lack of resistance of polyvinyl-resin glues to mechanical stresses induced by the shrinking or swelling of the wood.

Effect of elevated temperatures.—Because of the thermoplastic nature of the polyvinyl resins, it was desired to determine the resistance of joints glued with polyvinyl glues to temperatures that might prevail in the heat of the sun or near a radiator. Three yellow birch panels of three-ply $\frac{3}{16}$-inch construction were prepared with each of the 11 polyvinyl glues and also with a casein glue and a typical animal glue. Ten standard shear test specimens were cut from each panel. Two of these specimens from each of the three panels were tested at 75° F., two at 110° F., two at 160° F. and four were retained for the static loading tests to be described later. The average results of the plywood shear tests at each temperature are given in table 3. Of the polyvinyl glues, specimens glued with B, C, G, H, and K fell off in strength considerably and those with glue E slightly when the temperature was raised from room temperature to 110° F. When the temperature was raised to 160° F. specimens of all polyvinyl glues fell off in strength. At 160° F. the strength of specimens glued with the different polyvinyl glues varied from 14 to 348 pounds per square inch.

Static load tests.—Some of the specimens cut from the plywood panels described in the preceding paragraphs were conditioned to equilibrium with air at 80° F. and 65 percent relative humidity. They were then tested at these conditions under static loads applied in shear by means of a lever system (fig. 2). The number of specimens failing at intervals from 1 hour to 10 days under each of three load conditions was observed and recorded. The results of these tests are summarized in table 4. All specimens glued with animal or casein glue sustained 200 pounds in this static load test without breaking within 10 days. Of the polyvinyl glues, all failed within 10 days under a load of 200 pounds and some failed promptly under a load of 100 pounds. In all cases the failure was an elastic slippage of the glue in the joint with practically no failure in the wood.

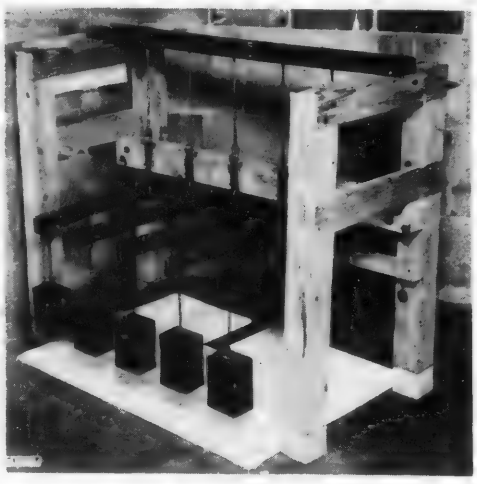

Fig. 2.—Glue joints in plywood specimens under static load tests.

Characterization.—The polyvinyl-resin emulsion glues examined may be generally characterized as follows:

1. The working life is indefinitely long and the stability in storage in tight containers is good.

TABLE 3.—EFFECT OF ELEVATED TEMPERATURES ON DRY SHEAR STRENGTH OF YELLOW BIRCH PLYWOOD SPECIMENS[1] MADE WITH POLYVINYL-RESIN EMULSION, CASEIN, AND ANIMAL GLUE

Glue	Specimens at 75° F. when tested	Specimens at 110° F. when tested	Specimens at 160° F. when tested
A	[2]403–31	[2]548–56	[2]348–18
B	526–27	342–6	235–3
C	463–4	85–0	14–0
D	314–2	587–4	196–0
E	654–80	600–58	271–10
F	569–90	672–87	231–0
G	782–53	518–14	193–0
H	272–1	172–0	112–0
I	414–54	588–74	320–6
J	514–20	568–48	329–15
K	430–3	149–1	86–1
Animal	400–15	335–4	322–2
Casein	451–29	442–18	368–2

[1]Three-ply, 3/16-inch yellow birch plywood at about 6 percent moisture content.
[2]The value before the dash is average shear strength in pounds per square inch; the value after the dash is average estimated wood failure in percent. Each value is the average of at least 6 specimens.

TABLE 4.—RESULTS OF STATIC LOAD TESTS ON THREE-PLY 3/8-INCH BIRCH PLYWOOD SHEAR SPECIMENS AT 80° F. AND 65 PERCENT RELATIVE HUMIDITY[1]

Glue	Load—100 pounds				Load—150 pounds				Load—200 pounds			
	No. of specimens failing in: Less than 1 hour	1 to 24 hours	1 to 10 days	No. of specimens not failing in 10 days	No. of specimens failing in: Less than 1 hour	1 to 24 hours	1 to 10 days	No. of specimens not failing in 10 days	No. of specimens failing in: Less than 1 hour	1 to 24 hours	1 to 10 days	No. of specimens not failing in 10 days
A				4				4		1	3	0
B	1	2	1	0	1	3		0	3	1		0
C	4			0	4			0	4			0
D			3	1			4	0		4		0
E				4		1	3	0		4		0
F				4			4	0		2	2	0
G		2	2	0		4		0	3	1		0
H	2	2		0	4			0	4			0
I				4			2	2			4	0
J			1	3			3	1		4		0
K	1	3		0	4			0	4			0
Animal				4				4				4
Casein				4				4				4

[1]In these tests four standard yellow birch plywood specimens glued with each glue and with a test area of one square inch were loaded in shear with each of three different loads. The number of specimens that failed completely within each of three test periods was observed and recorded.

2. The consistency and the nonvolatile content (generally between 50 and 60 percent) are generally comparable to other resin glues.
3. The dry joint strength obtainable varies widely. Some are capable of forming joints in maple that give high shear values with little wood failure.
4. The water resistance of the joints is low.
5. Thermoplastic properties are indicated by decreasing strength at elevated temperatures and by failure to sustain loads of moderate magnitudes over long periods at room conditions.

Developments Relating to Reduction in Glue-line Costs

While development of new glues, invention of more rapid and convenient gluing procedures, and increased production of chemicals often serve to reduce costs of gluing, the more common method of reducing glue-line costs is by the addition of inexpensive extenders.

In the addition of extenders, the problem usually resolves itself into one of adding sufficient inexpensive extenders to reduce significantly the cost per unit area of glue line, without affecting markedly the working properties of the glue and without reducing the quality and durability of the glue joints below that demanded by the intended service.

The use of extenders became important soon after the introduction of synthetic resin glues, but the use is not limited to the resin glues. Materials for the extension of animal glue and of casein glue are available on the market. The greatest use of extenders, however, has been in resin glues and the developments since the war appear to have been concentrated in that field.

Extension of Phenol-resin Glues

In their investigations of markets for farm products, Babcock and Smith[6] have shown that soybean meal, linseed meal, and corn gluten may be used to extend phenol-resin glues. Their work has indicated that high protein content and low water-absorbing capacity are desirable properties in extenders, that the extender should be low in water-soluble constituents, and that the resin should be comparatively low in molecular weight. Their results indicate that linseed meal is permissible in extenders only in small amounts, because of its high water-absorbing capacity and high proportion of water-soluble components. Solvent-extracted soybean meal contains 25 to 30 percent water-soluble components and, consequently, is unsuitable for use as an extender until these components have been at least partially removed. Centrifuged corn gluten contains 55 to 70 percent proteins, is low in water-soluble components, and has proved an acceptable extender for phenol-resin glues. Their data indicate that, when the resin:gluten ratio was 2:1, the mixture was capable of producing strong joints in yellow birch, mahogany, and yellow-poplar plywood. When the amount of gluten was increased, a decrease in the strength of the joints in yellow birch was noticeable, but even when the resin:gluten ratio was 1:1

[6] Extending Phenolic Resin Plywood Glues with Proteinaceous Materials. Glenn E. Babcock and Allan K. Smith. Ind. and Eng. Chem. Vol. 39, pp. 85–88 (Jan. 1947).

joints in mahogany and yellow-poplar plywood tested adequately high in dry strength.

The use of Douglas-fir bark[7] has been developed as an extender for phenol-resin glues. According to information from the manufacturer, the Douglas-fir bark extender is a proportioned blend of the three constituents of the tree bark; that is, cork, bast fiber, and amorphous powder. In this application the finely powdered bark is first thoroughly mixed with alkali, heated, and then cooled before incorporation with the resin. It is not certain whether there is any chemical reaction between the extender and resin under these conditions. Of the extenders used for phenol resins in the Pacific Northwest, approximately 25 percent is reported to be Douglas-fir bark. With suitable adjustments in the formulation of the resin, extensions as high as 40 percent of the weight of the dry resin are reported.

Extension of Resorcinol-resin Glues

Babcock and Smith have also investigated the extension of resorcinol-resin glues with corn gluten and with soybean meal.[8] Because of its greater dispersibility in the alcohol solution of the resorcinol resin, corn gluten was found to be more adaptable for the purpose than soybean meal. Extension with corn gluten was found to be most readily accomplished when the resin was prepared in the ratio of 1 mol resorcinol to 0.60 mol formaldehyde and the resin adjusted to a pH of 7.5. When the resin was so prepared, it appeared that an addition of corn gluten up to 80 percent of the dry weight of the resin had no marked effect on the initial dry strength and water resistance of joints in birch plywood. Data on the effect of extension on durability of the joints as measured by prolonged exposure tests were not included in the report.

Extension of Resin Glues with Walnut Shell Flour

English walnut shell flour has been a rather widely used component of resin glues for several years. When used in comparatively small amounts, it appears to improve the working characteristics without detracting noticeably from the strength or durability of the joints. When used for the primary purpose of improving working characteristics, it is often spoken of as a filler rather than as an extender.

The effect of variations in the amount of walnut shell flour added as a filler or extender to each of three types of resin glues was investigated at the Forest Products Laboratory. This extender was added in increasing amounts, together with additional solvent, to an intermediate-temperature-setting phenol-resin, an intermediate-temperature-setting melamine-resin, and a room-temperature-setting resorcinol-resin glue after the glues were mixed for normal use. When the percentage of filler, based on nonvolatile content, was less than approximately 28 percent for the phenol glue, 37 percent for the melamine glue, and 34 percent for the resorcinol glue, the reduction in dry and wet strength of joints appeared to be of no practical importance. This specific investigation did not include a determination of the durability of the extended glues.

At the request of the Tennessee Valley Authority, the Forest Products Laboratory investigated the possibilities of using black walnut shell flour in place of English walnut shell flour. The results of the work showed that the black walnut product would serve equally as well as English walnut shell flour as a filler for resin glue.

Extension of Urea-resin Glues with Flour

The extension of urea-resin glues with flour cannot be termed a "postwar development." Even before the urea-resin glues were introduced into the United States, extension with rye flour appeared to be accepted practice in Germany; promptly upon introduction into the United States, glue-line costs were reduced by extension with rye flour. It was soon found that wheat flour could be used in place of rye flour and extension with wheat flour became common.

Recent developments include some investigations by the glue manufacturers of suitability of different wheat flours, investigations of the effect of flour extension on working characteristics, and more detailed information of the

[7] Chemical Industries, Vol. 61, No. 1, p. 36 (July 1946).

[8] Extending Resorcinol Resin Glue with Corn Gluten. Glenn E. Babcock and Allan K. Smith. Modern Plastics. P. 153, No. 8, Vol. 153 (April 1947).

effect of extension with flour on durability of the joints.

Suitability of different wheat flours.—It seems that the hard wheat flours are preferred for use as extenders, and apparently second clear winter-wheat flour is often ordered. Attempts have been made to develop processing procedures that would permit the use of any wheat flour. The Forest Products Laboratory has no experimental data relating to the effectiveness of these modifying processes, and it is believed that the results have not appeared in the literature.

Effect of extension on working characteristics of room-temperature-setting urea-resin glues.—The Forest Products Laboratory is now investigating the effect of extending room-temperature-setting urea-resin glues on the working properties. The work is still in progress, but the data on a study of the gluing of yellow birch plywood, in its present incomplete form, indicate that:

a. Short assembly periods should be avoided when the weight of the flour exceeds the weight of the dry resin.
b. Somewhat erratic results may be expected when extended mixtures are used to glue wood containing more than about 9 percent moisture. As the extension was increased, joint strengths decreased more rapidly when the wood contained more than 9 percent moisture than when the moisture content of the wood was 9 percent and below.

Effect of extension on durability of joints in yellow birch plywood glued with high-temperature-setting urea-resin glues.—Shortly after the use of urea-resin glues became established in the woodworking industry, the Forest Products Laboratory initiated investigations to determine the effect of extending high-temperature-setting urea-resin glue on the strength and durability of joints in birch plywood.[9] Since rye flour was the extender in common use when the tests were started, the experimental mixtures were extended with this rather than with wheat flour, which came into use at a later period.

[9] Effect of Extending Hot-Press, Urea-Resin Glue with Rye Flour on Strength and Durability of the Glue Joints. Forest Products Laboratory Report Z1294 (April 1942).

a. Preparation of specimens for exposure tests.—Six glue mixtures were used to glue three-ply, $\frac{3}{16}$-inch yellow birch plywood panels from which the test specimens were taken. In all six mixtures the ratio of catalyst to resin remained the same, but the amount of extender varied in the different mixtures from none to twice the amount of dry resin. No preservatives were added to any of the glue mixtures.

From each panel, 30 plywood shear test specimens of conventional design were obtained. Of these five specimens were tested dry at a moisture content of approximately 6 percent and five were tested wet after soaking in water for 48 hours. All specimens from defective panels were discarded. The test values of specimens of panels shown to be suitable for further testing were tabulated according to the glue mixture used, and averages were determined for both wet and dry tests. These average values then served as controls and are shown in the first two rows of table 5.

The remaining specimens of the panels selected for further tests were arranged in sets, according to the glue mixture used. From each set of specimens glued with one glue mixture, four groups of 80 specimens each were selected for exposure (fig. 3).

One such group of specimens from each glue mixture was then soaked continuously in water at room temperatures. A second group from each glue mixture was exposed continuously in a room where the temperature was maintained at 80° F. and the relative humidity at 97 percent. A third group from each glue mixture was exposed to a repeating cycle that consisted of two days' soaking in water at room temperature, followed by 12 days' drying in air at 80° F. and 30 percent relative humidity, and a fourth group was subjected to a repeating cycle that consisted of two weeks of exposure at 80° F. and 97 percent relative humidity followed by two weeks at 80° F. and 30 percent relative humidity.

At the end of each interval of 2, 4, 6, 12, 18, 24, 30, and 36 months, five specimens were removed from each group and tested in a plywood shear-testing machine of conventional design. The test values of each such set of five specimens were averaged and the results are recorded in the body of table 5.

Fig. 3.—Arrangement of specimens for handling through exposure cycles. The unexposed specimens are from another test and are included to show the normal appearance of test specimens before exposure. In comparing the conditions of the different groups, primary attention should be paid to the condition of the individual specimens.

b. Continuous exposure to 97 percent relative humidity.—The effect of extending high-temperature-setting urea-resin glue with rye flour was most pronounced in the tests involving the exposure to 97 percent relative humidity and 80° F., which is a condition favoring the development of molds and wood-destroying fungi. Glue joints made with the urea-resin glue extended with 200 percent of rye flour barely had strength to hold the plies together at the end of the second month of exposure. Those made with urea resin extended with 100 percent of rye flour had lost nearly all of their strength by the end of the twelfth month. Joints made with the urea resin extended with 50 percent of rye flour showed greater resistance to exposure to warmth and dampness than the joints made with the more extended mixtures. At the end of 24 months, however, the joint strengths were very low, although most of the specimens were still holding together. The loss in strength of joints with 25 percent extension was gradual throughout the test period and less than that of the joints made with greater extension. By the end of the thirtieth month, however, the test values were low and the joints were no longer reliable. At the end of 36 months (fig. 3) the glue extended with 10 parts of flour showed somewhat lower test values than those of the straight or unextended glue. Apparently a 10 percent extension, however, did not reduce to a significant

TABLE 5.—COMPARATIVE DURABILITY OF JOINTS MADE WITH A HOT-PRESSED UREA-RESIN GLUE USED WITHOUT EXTENDER AND WITH DIFFERENT PROPORTIONS OF AN EXTENDER OF RYE FLOUR

Time of Exposure Months	Glue Without extender	Extended with 10 percent rye flour	Extended with 25 percent rye flour	Extended with 50 percent rye flour	Extended with 100 percent rye flour	Extended with 200 percent rye flour
			Average test values[1]			
None (control values)						
Dry[2 3]	507- 63	483- 83	458- 89	439-90	440- 90	429-83
Wet[2 4]	489- 96	478 -94	455- 90	426-71	405- 60	261- 8
			Soaked continuously in water at room temperatures[5]			
2	444- 81	426- 99	317- 66	376-53	366- 79	253-12
4	441-100	423- 81	359- 79	349-51	354- 71	235-13
6	401- 96	365- 50	350-100	297-41	300- 62	182- 2
12	396-100	379- 84	350- 80	322-61	351- 22	227- 3
18	340-100	328-100	311-100	245-20	246- 52	204-19
24	316-100	295-100	311- 92	247-68	240- 80	137-22
30	298-100	277-100	267-100	275-88	238- 82	172-29
36	313- 96	264- 96	284- 90	245-48	281-100	176-64
			Exposed continuously to 97 percent relative humidity and 80° F.[5]			
2	477- 99	470- 83	408- 43	284-16	231- 21	0-0[b]
4	393- 45	403- 50	337- 23	237-20	202- 19	25-0
6	366- 4	258- 20	235- 1	215-19	149- 16	13-0
12	309- 41	290- 40	215- 0	94- 0	79- 0	0-0[b]
18	309- 0	222- 36	140- 0	90- 1	0- 0[b]	0(18)[a]
24	155- 0	225- 20	138- 0	23- 0	18- 0	---------
30	198- 0	170- 20	79- 0	14- 0	0- 0[b]	---------
36	144- 0	108- 0	49- 0	32- 0	28- 0	---------
			Exposed to a repeating cycle that consisted of 2 days soaking in water at room temperatures followed by 12 days drying at 80° F. and 30 percent relative humidity[5]			
2	479- 92	376- 45	380- 76	343-39	351- 19	330-19
4	444- 44	392- 50	397- 42	410-23	378- 23	337-14
6	446- 1	460- 68	390- 22	447-57	366- 42	374-42
12	436- 12	357- 41	345- 26	308- 4	315- 24	264-20
18	511- 82	354- 28	331- 3	289-18	292- 22	310- 1
24	440- 81	345-100	214- 40	217-20	157- 0	166- 0
30	362- 0	331- 40	282- 40	312-19	246- 20	209-41
36	394- 0	299- 5	178- 19	281-20	272- 20	169-20
			Exposed to a repeating cycle that consisted of 2 weeks in 80° F. and 97 percent relative humidity followed by 2 weeks in 80° F. and 30 percent relative humidity[5]			
2	514- 80	435- 60	392- 31	419-30	325- 26	134- 0
4	524- 25	368- 49	371- 60	321-23	220- 30	0- 0[b]
6	476- 24	355- 11	329- 2	300- 0	181- 0	0(6)[a]
12	376- 21	250- 0	203- 2	124- 0	181- 20	---------
18	410- 12	290- 20	184- 0	108- 0	46- 8	---------
24	248- 0	309- 21	183- 0	111- 0	0(24)[a]	---------
30	235- 0	328- 30	124- 0	73- 0	---------	---------
36	187- 0	60- 0	91- 0	60- 0	---------	---------

[1] In each pair of values, the first represents average joint strength in pounds per square inch, the second represents wood failure in percent.
[2] Each value is an average of 100 specimens, 5 from each of 20 panels.
[3] Specimens tested when in approximate equilibrium with 30 percent relative humidity.
[4] Specimens tested wet after soaking for 48 hours in water at room temperature.
[5] Each value is an average of five specimens.
[a] Figures in parentheses indicate the month during which the last specimen in the group failed completely.
[b] In the five specimens taken for test the joints were still holding the plies together but the strength was so low that the specimens could not be gripped in the testing machine without failure.

degree the resistance of the joints to continuous high humidity. Specimens glued with the unextended urea-resin decreased gradually in joint strength, and at the end of 36 months the average test value was reduced to some 28 percent of the original dry test value (table 5).

c. Exposure to a repeating cycle of two weeks in 97 percent relative humidity followed by two weeks in 30 percent relative humidity.—Exposure to a repeating cycle of two weeks in 97 percent relative humidity followed by two weeks in 30 percent relative humidity proved to be more severe than the soaking-drying cycle. In many cases the specimens failed almost as rapidly as those exposed continuously in 97 percent relative humidity. Specimens whose joints were glued with a mixture containing 200 percent of rye flour had failed completely in this cycle at the end of the sixth month. Joints made with a mixture extended with 100 percent of rye flour failed completely in about 24 months. The test results were reasonably consistent in indicating a uniform decrease in durability as the amount of extender increased.

d. Exposure to a repeating cycle of two days' soaking in water followed by 12 days' drying in 30 percent relative humidity and 80° F.—The effect of extension of the glue on the resistance of the joints to a soaking and drying cycle was less pronounced than the effect on resistance to exposure to conditions favoring mold growth. Although irregularities and inconsistencies in the data are apparent, the resistance of the joints to wetting and drying

exposure appeared to decrease slightly as the amount of extender was increased.

e. Continuous soaking in water at room temperatures.—In general, continuous soaking in water proved to be the least severe of the exposure tests used in this experiment, but the results were reasonably consistent in indicating that the resistance of joints to continuous soaking decreased gradually as the amount of extension was increased. The resistance to continuous soaking was comparatively high, however, even for the joints made with 200 percent of flour added to the resin.

f. Dry strength and initial water resistance.—As the amount of extension was increased the initial water resistance of the joints fell off slowly and gradually up to an extension of 100 percent. When the extension was increased to 200 percent the decrease in water resistance was considerably greater. The effect of extension on the dry strength of joints was not pronounced. While the averages of the dry strengths showed a slow and gradual decrease as the amount of extension increased, it was not confirmed by a corresponding decrease in wood failure and the differences between the averages were small.

g. Characterization.—From these data, the following trends appeared to characterize birch plywood joints made with extended high-temperature-setting urea-resin glues:

(1) The effect of extension of urea-resin glue with flour on the durability of the joints was most pronounced when the joints were exposed to warm damp conditions favoring the development of micro-organisms. The effect of additional preservatives to the extended glue mixtures was not included in this study.

(2) The effect of extension on the resistance of joints to wetting and drying cycles was less marked than the effect on resistance to warmth and dampness, but in general the resistance fell off gradually as the amount of extension was increased.

(3) The effect of extension on initial dry strength, on initial wet strength, and on resistance to continuous soaking was not marked, although a decrease in all three properties was noticeable as the amount of extension increased.

Discussion

Mr. Glen P. Harris (Monsanto Chemical Company): This paper presents extensive data on the investigation of the polyvinyl-resin emulsions made by the Forest Products Laboratory. The data indicate that, when plywood specimens bonded with this type of adhesive were raised in temperature from 75° F. to 110° F., perhaps only three of the eleven glues tested showed a large loss of strength. We recently conducted a somewhat similar investigation in our laboratories, using five representative adhesives of this type. However, block-shear specimens were used instead of plywood-shear specimens. Under these conditions, all of the glues tested lost at least 50 percent of their strength when the glue-line temperature was raised from 75° F. to 100° F. This indicates the differences in evaluation of an adhesive that may be obtained due to the type of specimen that is used.

In this paper on Postwar Developments, data are included from a Forest Products Laboratory Report issued in April 1942 on extensions of hot-press urea-resin glues with rye flour (which is not used at the present time). Under the accelerated aging exposure condition of 80° F. and 97% relative humidity, the effect upon bond quality of increasing percentage of flour extensions is clearly shown, and accounts for the recommendations of the urea resin manufactures to use low flour extensions. This exposure condition, producing an equilibrium moisture content in wood of approximately 27 percent, which is favorable for the development of wood decay, required two years to reduce the strength of specimens bonded with the 25 percent flour extensions to some 27 percent of its original strength. It would be interesting to observe the loss of strength of several species of veneer, including yellow birch, when exposed to this condition.

Due to the variety of species and the various types of constructions used by the consumers of urea resin, it is difficult to ascertain what correlation exists between this accelerated aging test and the long term durability of urea-resin-bonded assemblies under exposure to normal conditions. While the study does show differences in the durability of the bond obtained, dependent upon the flour extension, we believe that this should be considered an abstract study until this correlation is determined.

Metal to Wood Bonding

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By taking advantage of the physical and structural properties of both components, metal and wood, many applications for plymetal products have been developed within the last decade. The commercial significance of these products has resulted in the development and use of a variety of adhesives and techniques for bonding metal to wood. The more recent developments which take advantage of the adhesive properties of several synthetic resins and rubbers are resulting in many practicable commercial applications.

THERE is a wide gap between the properties of metal and wood. Metals have comparatively high densities, are fireproof, and have high hardness and strength characteristics. In thin sheets, they lack rigidity and stiffness as well as good sound and heat insulation values. Wood is characterized, on the other hand, by its light weight, combustibility, softness, and good insulating values. In the form of plywood it possesses good strength properties especially when considered on a unit of weight basis. By bonding a comparatively thin sheet of metal to wood or plywood, to make a product which in this paper is termed *plymetal,* it is possible to combine the good qualities of both materials and at the same time to minimize the effect of the undesirable qualities. Thus the wide gap between metal and wood is bridged.

As compared with plywood, the commercial production of metal-faced plywood panels is very new. Plywood dates back to the time of the Pharaohs, while plymetal has been produced for only a little over a decade. Although the number of producers of plymetal as compared with the producers of plywood is small, the estimated production of a million square feet per month in this country is of economic importance. Metal-faced panels have been produced in England for many years. There were at least two factories in Germany producing a limited quantity before and during the last war. It is expected that production will soon be under way in Australia.

Properties of Plymetal

That there are practicable uses for metal-faced plywood becomes quite evident when one considers the following general properties of such a material.

1. As a structural material, based upon values per unit of weight it has very high resistance to bending and buckling.
2. The wear and abrasion resistance of the surface is comparable to a heavy metal sheet.
3. It possesses high impact resistance.
4. It offers appreciable fire resistance. When subjected to intense heat, it will not buckle under load as quickly as sheet metal.
5. It gives a good painting surface for exterior exposures, where visible wood grain is objectionable.
6. It offers an impervious barrier to moisture transmission and thus great dimensional stability.
7. It generally can be worked with ordinary wood working tools.

From the above, many possible applications become apparent. Insofar as commercial applications are concerned, the transportation field is the principal user. In the building of the modern coach, parlor and sleeping cars for railroads, advantage is taken of the high structural strength of metal-faced plywood when considered on a unit of weight basis. The same applies to the sides of the Diesel locomotives,

as well as the bodies of both large and small automotive delivery trucks. Although limited in volume, a very useful application has been developed for panels having thin aluminum faces and balsa core as structural units in high speed aircraft.[1] The fire retardant and insulating characteristics of plymetal have resulted in its use for partitions, doors, and the like where advantage could be taken of these properties.

Because of the dimensional stability, flatness, and stiffness inherent in panels having metal on both faces, this construction has been found very practicable for such applications as doors of commercial truck bodies, sliding doors in show cases and doors of elevator cabs, as well as the complete cab. Frequently, for the latter use, a fancy veneer face is applied to the plymetal panel to enhance its appearance.

Since the metal surface gives to the structural material the added characteristic of imperviousness to moisture and gases, plymetal panels were used during the war for making containers to transport ammunition and powder. For many years fumigation vaults, of the commercial and household types, have been made of metal-covered plywood to insure airtightness along with structural strength. In order to take full advantage of the imperviousness of the metal in a plymetal panel, many ingenious and practicable methods of sealing the edges of the panel have been developed.

Another application involving a combination of metal and wood which is finding many applications, chiefly from a decorative standpoint, is a panel consisting of a thin wood veneer bonded to a relatively thick metal sheet.[a, b] Structurally, this type of panel does not have the advantages of a plymetal panel, but it does offer the possibilities of a wood surface with the dimensional stability of metal.

Two kinds of metal-faced plywood find commercial applications: (a) plywood with metal on one side only and (b) plywood with metal on both sides. The applications for the first are primarily not structural from an engineering standpoint. These panels are used where a smooth, paintable, abrasion- and impact-resistant exterior surface is desired, such as for the side panels for commercial truck bodies. Structurally these panels behave like an angle or a T section. The flange of the T corresponds to the plywood. Although this is an unbalanced construction, it has many applications in the commercial body field. Because of the unbalanced nature of the construction, it is not possible to maintain the ultimate in flatness. An unsupported panel will tend to twist and warp when exposed to varying weather conditions. This is brought about by the characteristic of wood to shrink and swell with changes in moisture content. Since the wood on the one side is protected by the impervious metal sheet, it is not subjected to the same changes in moisture as is the opposite unprotected face. Thus the stresses are not uniformly distributed throughout the panel and warpage results.

For those applications where high stiffness and uniformity in flatness as well as a smooth, abrasion, and impact-resistant surface are desired, the panel having metal on both sides is required. This product simulates the structural properties of an I beam or channel section. The flanges of the I beam correspond to the metal and the web to the plywood.

Referring to Table 1, in which a comparison is made between the stiffness of sheet aluminum, sheet steel, plywood, metal-one-face, and metal-two-faced plywood, it will be noted that there is an appreciable difference in weight for the various materials having about the same stiffness. By way of example, this table indicates that approximately the same stiffness factor obtains for a 6-gage steel sheet as for a $\frac{5}{16}$"-aluminum sheet, a ¾"-plywood panel, a $\frac{5}{16}$"-steel-faced panel, and a ½"-aluminum-faced panel, weighing 8.1 lb., 4.4 lb., 2.1 lb., 2.4 lb., and 1.65 lb. per square foot, respectively.

Requirements of Adhesives

In bonding metal to wood it must be recognized that two dissimilar materials are involved. Wood is comparatively soft, rough, and porous, while metal is hard, smooth, and impervious. The bonding agent must therefore possess adhesiveness for both surfaces. Frequently, the adhesion of a material for a surface such as metal has been referred to as specific adhesion. Adhesion here apparently depends upon the chemical nature of the surfaces and the adhesive and involves to an appreciable extent polar,

[a] Flexmetl, U. S. Plywood Corp.
[b] Ornametl, Haskelite Mfg. Corp.

TABLE I.—COMPARATIVE STIFFNESS FACTORS

SHEET STEEL				SHEET ALUMINUM				PHEMALOID* PLYWOOD			
Thickness			E I	Thickness			E I			E I	
Frac.	G. A.	lb. sq. ft.	E. I.	Frac.	G. A.	lb. sq. ft.	E. I.	Thickness	lb. sq. ft.	L	T
--	20	1.5	.1	--	--	----	-----	----	----	----	----
--	16	2.5	.6	--	16	.7	.1	----	----	----	----
--	12	4.4	3.1	--	12	1.1	.4	----	----	----	----
--	10	5.6	6.5	--	10	1.4	.9	----	----	----	----
--	8	6.9	12.0	--	8	1.8	1.8	----	----	----	----
--	6	8.1	20.0	--	6	2.3	3.6	----	----	----	----
1/4	--	10.2	39.0	1/4	--	3.5	14.0	1/4	.70	1.6	.3
5/16	--	12.7	76.0	5/16	--	4.4	26.0	5/16	.96	3.3	.3
3/8	--	16.3	140.0	3/8	--	5.3	43.0	3/8	1.03	5.5	1.0
7/16	--	17.8	210.0	7/16	--	6.2	69.0	7/16	1.23	6.3	4.2
1/2	--	20.4	310.0	1/2	--	7.1	110.0	1/2	1.39	8.9	6.6
--	--	----	-----	5/8	--	8.8	200.0	5/8	1.73	20.0	10.0
--	--	----	-----	3/4	--	10.6	360.0	3/4	2.10	28.0	26.0
--	--	----	-----	--	--	----	-----	7/8	2.44	52.0	39.0
--	--	----	-----	--	--	----	-----	1.	2.76	77.0	54.0

PLYMETL*												
	.021 Steel 1 side		E I	.021 Steel 2 sides		E I	.015 Al. 1 side		E I	.015 Al. 2 sides		E I
Thickness	lb. sq. ft.	L	T	lb. sq. ft.	L	T	lb. sq. ft.	L	T	lb. sq. ft.	L	T
1/4	1.46	3.2	1.9	2.25	17.	17.	.84	2.3	1.2	1.01	4.9	4.3
5/16	1.62	6.2	3.8	2.40	28.	27.	1.00	4.5	2.3	1.17	8.2	7.0
3/8	1.77	12.0	5.4	2.56	43.	40.	1.15	7.7	3.2	1.43	13.0	10.0
7/16	1.96	18.0	11.0	2.75	62.	55.	1.34	12.0	5.6	1.52	19.0	15.0
1/2	2.10	22.0	18.0	2.89	80.	74.	1.48	16.0	9.4	1.65	26.0	20.0
5/8	2.42	43.0	29.0	3.20	130.	122.	1.80	28.0	17.0	1.98	43.0	35.0
3/4	2.75	72.0	48.0	3.48	192.	182.	2.13	46.0	29.0	2.35	65.0	55.0
7/8	3.05	110.0	81.0	3.87	269.	255.	2.46	68.0	48.0	2.63	94.0	81.0
1.	3.40	150.0	122.0	4.21	359.	343.	2.78	94.0	72.0	2.98	129.0	114.0

*Trade mark of Haskelite Manufacturing Corporation.
EI = Modulus of elasticity x Moment of Inertia = Stiffness factor.
L = Face grain of plywood next to the metal, Longitudinal.
T = Face grain of plywood next to the metal, Transverse.

molecular, and electrostatic forces. Most of the well known woodworking glues are no good for bonding metal to wood because they do not possess the proper adhesive forces. In bonding together two pieces of wood the same polar, molecular and electrostatic forces may be active, but because of the fact that the adhesive can penetrate pores and openings in the wood surface and form a mechanical bond, these forces are not as significant. It is thus obvious that in metal to wood bonding the adhesive must be one which is able to penetrate the porous wood surface to give the mechanical type of adhesion and at the same time exert the specific type of adhesion to the impervious and comparatively smooth metal surface. The author appreciates that the above may not be entirely accurate, but it does in a measure explain why all adhesives will not give a bond between metal and wood. Considerable work has been done in studying the nature of adhesion and the findings published to date[2, 3] are important and of interest, although much desired information is still lacking. As a result, much of the work being done in developing metal to wood adhesives is of the trial and error type.

Both metal and wood change in dimension with a change in temperature. The approximate coefficient of thermal expansion (increase in length per unit length per degree C. increase in temperature) for aluminum is 25×10^{-6}, for steel 10×10^{-6}, and for wood 5×10^{-6} along the grain and 40×10^{-6} across the grain. These values are approximate, but they do indicate the significant difference between metal and wood. Another factor which frequently associates itself with changes in temperature is that the wood dries out and shrinks as a result of an increase in temperature, while the metal expands. Therefore, in a metal-to-wood construction it is essential that the adhesive possess sufficient flexibility or elasticity to compensate for this difference. Unless the adhesive serves as the flexible coupling between the two dissimilar materials, the stress due to the difference in expansion when subjected to temperature changes may cause the panel to twist and warp, or may even rupture the bond if the stress should exceed the strength of the bond.

The need of a certain amount of elasticity in the adhesive is also very important in metal-one-face panels which are subjected to moisture changes. As previously mentioned this type of panel will warp because of the dimensional changes of the wood with changes in moisture content. Unless the adhesive has some elasticity, the severe stress due to these dimensional changes may cause the bond to rupture.

Another reason why the adhesive should possess some flexibility and elasticity is that for many applications these panels are subjected to considerable vibration. An extremely hard and brittle adhesive will not be able to take the shock of continuous and severe vibration.

This elasticity or flexibility is very often associated with thermoplastic materials. Depending upon the ultimate use of the plymetal, it is obvious that the plastic characteristic of the adhesive should not change appreciably in the temperature range to which the product is subjected. Even if the adhesive has the needed flexibility at normal room temperatures, if it becomes exceedingly brittle at temperatures in the range of let's say —20 degrees F., such an adhesive would be unsatisfactory for panels on railroad cars and trucks operating in most parts of our country. On the other hand, if the adhesive becomes noticeably thermoplastic at an elevated temperature to which the structural panel might be subjected, it would be objectionable because the stress due to the difference in thermal expansion or to the weight of the unsupported metal sheet might cause creep or even delamination.

One very common commercial method of attaining the flexibility has been the insertion of a layer of cloth between the metal and the wood.[4] This permits the use of rather hard and brittle adhesives, since the partially glue-impregnated cloth gives the necessary flexibility Another somewhat similar idea involves the bonding of cloth or other fibrous material to the metal sheet by means of a low temperature solder. In this product the bonding adhesive is used only between the wood and the cloth.[5]

Another property which should be inherent in a good metal-to-wood adhesive is water resistance. The degree to which this is necessary depends, of course, upon the ultimate use of the product. A very significant use of metal-one-side panels is for small delivery trucks. In this application the edges of the panels may be exposed to some very extreme moisture conditions. Under such conditions the adhesive must be not only water insoluble but must also maintain its adhesive strength.

Since the metals most frequently considered and used for plymetal are subject to corrosion, it is essential that the chemical nature of the adhesive will not cause or aid in the oxidation of the metal. In connection with this phase of the problem, it is also very essential that the moisture content of the core or plaque of a metal-two-side panel be kept as low as possible. It may have been observed that corrosion occurs much more quickly and severely on an area of sheet metal which is in contact with a piece of wood, than in the area exposed to the atmosphere. Although it may be suspected that this is due to the chemical composition of the wood, that usually is not the cause.[6] It is rather the result of the higher concentration (more water per unit volume) of moisture in the wood than in the atmosphere. It is therefore essential that the moisture in the panel assembly be kept as low as possible and also that the adhesive be of such a composition that it will not foster corrosion. It is not considered advisable to use metals which have very low corrosion resistance, such as black steel, if the adhesive does not possess a marked degree of corrosion inhibition.

No matter what adhesive or method of bonding is employed, certain basic procedures are necessary. A very important item is a proper surface on the metal.[7, 8] The first consideration is that the sheet must be free from oil and grease and also from any appreciable amount of loose oxides. Even the finger marks resulting from normal handling result in poorly bonded areas. Another means of improving the strength of the adhesive bond is to roughen or etch the surface. The more highly polished the metal surface is, the less will be the bond strength, because the adhesion is dependent entirely upon those forces considered to give specific adhesion with no mechanical forces functioning. Another important factor in obtaining uniform and well-bonded panels is the necessity of using wood or plywood and metal which have uniform thickness. In general, the thickness of the adhesive film is so small that it will not take care of variations in material thicknesses of much more than 0.002 in. This, of course, also presupposes, as for all plywood gluing, the use of adequate gluing pressures and good presses.

Methods of Gluing

The bonding of metal to wood can be divided into two general categories, as based upon the general gluing procedures. The first

is the cold-press method which, as the name implies, requires the use of simple cold-press gluing equipment and technique. The second is the hot-press method, which requires the use of some means of heating the assembly while it is under pressure in order to form a glue bond. Several typical adhesives representing each of these two categories will now be considered.

I. Cold-Press Method

A. *Protein-latex type adhesive*

An example[9, 10, 11] of this type of adhesive is the combination of casein glue and natural or synthetic rubber latex in a water solution having solids concentration between 25 and 50 percent. The adhesive sets by means of a loss of water from the glue line into the wood plaque. It is applied to either or both the wood and metal surfaces by brush, roll coater, or spray. Since adhesion is accomplished as with cold-setting wood adhesives, it is necessary to maintain maximum press time. Maximum strength is developed over a period of several days. By varying the ratio of protein to rubber, it is possible to alter the strength and flexural properties over a wide range. This type of adhesive is considered to have good tensile and shear strengths with very good flexural properties. It possesses a moderate degree of water resistance. The chief advantages are its comparatively low cost and the requirement of rather simple cold-press equipment. In contrast with the hot-press types, it also permits making reasonably flat metal-one-side panels. The chief disadvantage is that the high water content of the glue results in a significant increase in the moisture content of the assembly, with subsequent increase in possibility of corrosion of the metal at the glue line.

B. *Combination primer and cold-setting glue*

Within the past few years there have been developed for commercial production several adhesives of this type.[12, 13, 14] In general, the procedure is to apply to the metal surface a primer which has a marked degree of flexibility and good adhesion to metal. It is applied by one of the conventional methods, allowed to dry, and then baked or cured for several minutes at temperatures usually exceeding the boiling point of water. To this priming coat is applied a cold-setting glue, such as the urea, resorcinol, or resorcinol-phenol type of wood adhesives, using the usual wood-bonding techniques. This type of bond generally possesses a high degree of water resistance and further has the advantage of not adding appreciably to the moisture content of the panel. The bond strengths, such as tensile and shear, are very good. Because of the inherent brittleness of the adhesive, this combination does not give the degree of flexibility that is attained with the protein-latex type. The additional operations, as well as amount and cost of materials, result in a high glue-line cost.

C. *Rubber cements*

This includes a large group of cements having synthetic or natural rubber as the base in an organic volatile solvent. In general, these adhesives must be applied to both surfaces to be glued and allowed to dry for a specified time. The surfaces must be placed in contact with each other before too much solvent has escaped, in order to properly bond. The pressure need not be very great and the time under pressure is very short. These adhesives are frequently referred to as pressure-sensitive or contact glues. This type of glue bond is very flexible and possesses a limited amount of strength. The high cost, and the presence of volatile inflammable solvents, are disadvantages which must be considered.

II. Hot-Press Method

A. *Thermoplastic-type adhesive*

In the strict sense of the word these adhesives are not hot-setting, although they must be heated in order to be effective. In this group can be placed many proprietary asphalts, rubber cements and resin combinations involving acetates, vinyls, etc. Each of these possesses distinct properties and is useful for many limited applications. In general, the chief disadvantage is that it is necessary to heat and cool the assembly under pressure. This involves comparatively costly equipment, as well as being very time-consuming and impracticable for large panels.

B. *Rubber cements*

Although not considered of too great commercial importance, this type of adhesive has been used. It involves the application of a solvent-type cement to both surfaces to be bonded, with sufficient time for drying and the

application of one or more additional coats of the same or a somewhat similar material. Before putting in a hot press for vulcanizing the rubber, it is essential that volatiles be low. The vulcanizing requires several minutes at high temperatures. The resultant bond is very good and is generally considered to possess all the desirable physical properties. The cost of the material, together with the lengthy procedures and not too simple handling techniques, have resulted in very limited commercial applications.

C. *Resin-rubber combination*

Since 1940 considerable impetus was given to the development of metal-to-metal adhesives. Many of these adhesives have also found practicable application for bonding metal to wood.[14, 15, 16] The designation of resin-rubber combination is here intended to be broad and all of the newer adhesives will be included in this category, since the formulations of many have not been disclosed except in a very general way.[c, d, e, f] Rather than discuss each adhesive separately, it is intended here to give some of the working characteristics of a few which are more or less representative of many now being used commercially.

The most widely publicized adhesive in this group is *Cycleweld*.[g] There are several formulations included in this designation of cements. The cement is an organic-solvent solution and is applied to each surface to be bonded by spray, brush application, or roll coater. It is then air dried at room temperature for 15 to 20 minutes followed by a precure of 30 to 45 minutes at 170 to 180° F. The parts are then assembled and subjected to a pressure of 25 to 150 lbs. per sq. in. for one minute or longer at temperatures between 325 and 400 degrees F. The resultant bond has a reasonable degree of flexibility, as well as very good tensile and shear strengths in the dry. The necessity of applying reasonably liberal amounts of the cement to each surface to be bonded, with a comparatively expensive material based upon the solids content, as well as the need for careful control in drying and precuring and very high bonding temperatures, have limited the use of this cement for bonding large panel areas.

Another adhesive which is used commercially is *Redux*.[h] The gluing process is based on the use of two separate components, a liquid and a powder. The liquid component is applied to both metal and the wood by brush, spray, or roll coater. Immediately after applying the liquid to the metal, the powder is sifted on the wet surface in sufficient quantity to cover it entirely and any surplus is removed by light tapping. The surfaces are then allowed to air dry or may be force dried to evaporate essentially all of the solvent. Open assembly times of a few minutes to several days are satisfactory. The wood and metal surfaces are brought together, placed under simultaneous heat and pressure (approximately 250° to 300° F. and 50 to 250 psi respectively) for 10 to 30 minutes. The resultant bond has good impact and creep-resistant properties, as well as good water resistance. It is somewhat thermoplastic at temperatures approaching the boiling point of water, as evidenced by a decided reduction in shear strength at these temperatures. A reasonably good bond is obtained with a wide range of metals, although it does not seem to give best results with aluminum.

D. *Film glues*

Although never considered practicable in this country, the Germans did use *Tego glue film* for making plymetal.[17, 18] The sheet of film is interleaved between metal and the plywood and subjected simultaneously to heat and pressure. In general, the bond tends to be brittle and results to be very erratic, unless the moisture content of the film and of the wood are very closely controlled. Rapid loading and closing presses are essential. A rough metal surface also is conducive to good gluing.

More recently there have appeared in this country adhesives in dry-film form which give indications of becoming commercially significant. The first of these is *Redux film*. The film is interleaved between the metal and the wood and the assembly placed into a quick-closing hot press to avoid curing of the resin before application of pressure. The recommended glu-

[c] Cordo, Cordo Chemical Corp.
[d] Pliobond, Goodyear Tire & Rubber o.
[e] Reanite, U. S. Stoneware Co.
[f] Metlbond, Consolidated-Vultee Aircraft Corp.
[g] Chrysler Corporation.
[h] Resinous Products & Chemical Co.

ing conditions are 275 to 300° F. for 5 to 15 minutes and normal hot-press plywood-gluing pressure. The moisture content of the wood component of the assembly should be between 7 and 10 percent at time of gluing. The glue bond possesses essentially the same characteristics as mentioned in the Redux discussion earlier.

Another adhesive of very recent development is referred to by the manufacturer as a *Thermosetting adhesive film.*[1] This is supplied in tack-free sheets approximately two mils thick. This film, when subjected to heat and pressure, first softens and then cures to a less thermoplastic state. The film shows a high degree of adhesion to wood and metals. The recommended curing schedules for bonding aluminum to ¼"-plywood at glue-line temperatures of 275, 300, and 350 degrees F. are 20, 15, and 10 minutes, respectively. This film is of such recent development that the author has not had opportunity to evaluate the properties of the resultant bond. It has been observed that the bond possesses a good degree of flexibility as well as good strength characteristics under normal atmospheric conditions.

No one adhesive or type of adhesive can be considered to give what is needed for all ply-metal applications. Rather it is necessary to choose that one which, based upon economical factors, production problems and facilities, and ultimate application, is most practicable. The hot-press method, involving thermosetting synthetic resins in conjunction with synthetic rubber formulations, has produced results which have attracted much attention. However, the need for carefully controlled techniques and comparatively large investment in equipment has limited this method. The method is not usable for metal-one-face panels because of the excessive warpage which results with this construction when bonded by the hot-press method. On the other hand, the cold-press method requires less costly equipment and gluing technique and does present fewer problems with respect to lack of panel flatness. At the same time, the quality of glue bond obtainable with the adhesives which permit cold gluing is not considered as great as is obtainable with the hot-press adhesives.

[1] Minnesota Mining & Mfg. Co.

Conclusion

In conclusion, it can be said that, as a result of the impetus given during the war to metal-to-metal bonding, the recent developments in techniques and adhesives for metal-to-wood bonding have been significant. It is anticipated that the effects which are being exerted in the field of basic research, to more fully understand the fundamentals of adhesion, will appreciably extend the possible applications of products based upon combinations of metal and wood.

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(16) "Wood to Metal Adhesives" by T. D. Perry, Mechanical Engineering, Dec. 1946, p. 1035–1040.
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Discussion

Mr. Arthur L. Smith (The Resinous Products and Chemical Company): This is an excellent summary of the art of metal to wood bonding and the applications to which they may be put. I think every one will agree that the recent advances in adhesives for metal to wood open up many new fields of application. I should like to emphasize one thing—the importance of cleaning the metal surface. Of three methods we use in our laboratory, (1) acid etch, (2) solvent cleaning with ethylene dichloride, and (3) scouring with alkaline cleanser, we have found the acid etch to be most satisfactory.

In any event, there is a very simple test for a "clean" metal surface: If water will spread uniformly in a film over the entire metal surface without any tendency to "break" or crawl, then the surface is clean. If the film of water breaks or crawls, it is a good indication that the surface is not clean.

Mr. Charles B. Hemming (United States Plywood Corporation): Mr. Tigelaar points out that, where metal is to be attached to one side only of a panel, the best and surest way to obtain flatness is to use cold bonding, which, of course, means using a casein-rubber latex or similar type adhesive. He also comments, with due caution, that such bonds are not considered to be of the highest grade, that is to say, weather-proof. We have taken the same position but, after many outdoor durability tests on such panels with unprotected edges, we have been unable to substantiate the general attitude that such bonds are not durable provided that actual continued immersion in water does not occur. These observations, coupled with the knowledge that large quantities of such constructions have been in use for a considerable number of years, prompts me to ask you how you actually feel about the durability of these adhesives outdoors.

Mr. Tigelaar: It would seem that such constructions are in fact durable outdoors. We know of milk wagons using such constructions which have been in service for 25 or 30 years. In fact some of the earlier ones contained adhesives which were composed mostly of casein, and these are still in good condition.

INFORMAL BANQUET PROGRAM

Friday, October 31st

7:00 p. m. **Main Dining Room**

GENERAL DINNER

Presiding ---------- GEORGE A. GARRATT
Dean School of Forestry, Yale University *(Vice-President, FPRS)*

Toastmaster ---------- PHIMISTER B. PROCTOR
Technical Director, Oregon Forest Products Laboratory, Corvallis, Oregon

Principal Speaker ---------- HENRY T. HEALD
President, Illinois Institute of Technology, Chicago, Illinois
Subject: FINANCIAL SUPPORT FOR RESEARCH

Representatives of Organizations Interested in Forest Products Research:

HERBERT A. VANCE, *President,* Vance Publishing Company, Chicago, Illinois (Publisher of *American Lumberman* and *Wood*)

T. A. MCELHANNEY, *Superintendent,* Canadian Forest Products Laboratories, Ottawa, Canada

JAY H. PRICE, *Regional Forester,* U. S. Forest Service, Milwaukee, Wisconsin *(Member of the Council, Society of American Foresters)*

RICHARD A. COLGAN, JR., *Executive Vice-President,* National Lumber Manufacturers Association, Washington, D. C.

S. G. FONTANNA, *Deputy Director,* Michigan Department of Conservation, Lansing, Michigan

FRED W. GOTTSCHALK, *Technical Director,* American Lumber and Treating Company, Chicago, Illinois *(President, FPRS)*

LAWRENCE H. WHITING, *President,* American Furniture Mart, Chicago, Illinois

GEORGE A. GARRATT, *Dean,* Yale University, New Haven, Connecticut *(Vice-President, FPRS)*

TECHNICAL SESSION III

Saturday Morning, November 1, 1947

General Subject: Preservation and Seasoning; Miscellaneous

Chairman: Bror L. Grondal, Professor of Forestry, University of Washington, Seattle, Washington *(Past Chairman, FPRS)*

Recorder: Jac. H. Tigelaar, Director of Research and Tests, Haskelite Manufacturing Corporation, Grand Rapids, Michigan *(North-Central Board Member, FPRS)*

Recent Developments in Wood Finishing

G. G. Sward

Assistant Director, Scientific Section, National Paint, Varnish and Lacquer Association, Inc., Washington, D. C.

Wood is finished in order to preserve or enhance its beauty; or to preserve and decorate it when used for its mechanical properties. For thousands of years naturally occurring materials were used. Today hundreds of synthetic materials have practically displaced the natural ones.

Wood surfaces commonly painted include furniture, toys, sporting goods, handles, boats, fences, houses, barns, etc. They may or may not be exposed to the weather. The finishes may be clear or opaque.

The transition from oleoresinous finishes to lacquer for furniture; from single pigment-single oil paints to multi-pigment-treated oil paints for houses is noted.

Methods of application affect decisions as to type of paint to use. Spray application dominates industrial finishing and is making inroads on maintenance finishing.

WOOD is a friendly material. It is warm to the touch, has individuality in its grain, is yielding and yet strong. To preserve its beauty,—yes, even to add to it —we "finish" it with varnish or other transparent material. Where we use certain types of wood as a structural material because of its convenience or mechanical properties, rather than for its beauty, we may finish it in color with paint or enamel. But instinctively we seem to know when a painted surface is wood. Its identity is not easily lost. Wood is a friendly material.

Until about 200 years ago, people made their finishes with whatever natural materials they had at hand, or with a few synthetic materials that they accidentally learned how to make. Over 20 centuries ago the Chinese finished wood with the exudation of a tree related to our poison ivy; Noah used natural asphalt on his ark; the Indians (India) used lac, the secretion of an insect. From the 18th Century until 40 years ago, varnish was made by cooking linseed oil with natural resins of indeterminate composition, and white paint was made with a single pigment (white lead) and raw linseed oil.

Now, let's see what we are using today.

New Raw Materials

Just to name a few of the materials added to the list of finishes during the past 25 or 50 years, we have tung, castor and soybean oils, and their derivatives; phenolic, urea, vinyl, rubber and alkyd resins, synthetic iron oxides, phthalocyanine blue, zinc yellow, titanium dioxide, and aluminum pigments; solvents such as petroleum spirits, ketones, butyl acetate, ethers of glycol, and butanol.

Types of Surfaces

Wood surfaces that are commonly painted or otherwise finished include furniture, wall cabinets, trim, toys, sporting goods, tool handles, boats, lawn furniture, fences, houses, barns, farm machinery, etc. Some of these are protected from the weather at all times, some are exposed to the weather intermittently, and some are exposed continuously. This observation gives us a scheme for classifying finishes, namely, into those designed for interior and exterior surfaces. Another classification was mentioned in my opening remarks, namely, that of transparent and opaque finishes.

Finishes for Furniture

Most furniture wood is selected for the beauty of its grain and we use clear finishes to bring out, increase, and preserve that beauty. Twenty-five years ago the principal materials in use were three: (1) oleoresinous varnish, (2) spirit varnish, and (3) oil rub; oleoresinous varnish was by far the dominant finish. Today, probably 70 percent of the furniture manufactured in the United States is finished with cellulose nitrate lacquer, a few percent with low-temperature baked urea-formaldehyde, and the rest with air-drying oleoresinous varnish. Furniture manufacturers like the fast drying of lacquer, because dust has less time to

—*Courtesy Industrial Finishing.*

Spraying chairs with enamel.

settle on the finish, and it speeds production. They like the toughness of lacquer, because less printing takes place during packing and shipping. The ultimate owner likes lacquer because of its clarity, its toughness, non-printing quality, and moderate degree of alcohol resistance.

The urea-formaldehyde finish equals lacquer in speed of drying, but the required oven is an added expense. This finish is also equal to lacquer in toughness and print resistance, and excels it in resistance to alcohol and other solvents. Oleoresinous varnish has the advantage of low cost, partly because of its high solids content and partly because of its ingredients.

The principal disadvantage of lacquer is the relatively low percentage of solids it contains. However, this disadvantage is being whittled down. Twenty years ago, the development of low-viscosity cellulose nitrate put lacquer into the race. In the last few years still further reduction in viscosity has been effected. Whereas ordinary lacquers contain 15 to 20 percent of solids, this last development boosts this content to over 30 percent. Finally, the device of warming the lacquer to reduce the viscosity and to get higher solids at spraying consistency is being used to a limited extent. The hot-spray lacquer contains up to 40 percent of solids.

The best clear furniture finish probably is one that is built up of a single material. All coats are then compatible and fuse into one homogeneous mass. But building up a finish in this way on open-grain woods, such as walnut and mahogany, is entirely too expensive for industrial finishing. Only the amateur hobbyist can justify the time and material. Hence, the industrial finisher uses filler to build up the open grain, then applies a sealer, and finally sands the surface smooth in preparation for the final coat or coats. At times, the finisher demands more and more ease-of-sanding in the sealer, until it becomes a weak point of the finish. Fortunately, good finishers realize that extreme ease-of-sanding and high quality are incompatible; that there is a limit below which they must not go. Good finishers know that the extra cost of quality finish is so little that it is hardly noticeable in the cost of the furniture.

Non-Grain-Raising Stains

Another development in furniture finishing is that of N G R (non-grain-raising) stains. Water-soluble stains give perhaps the clearest and most permanent effects, but have two drawbacks: (1) They dry relatively slowly, and (2) they raise the grain of the wood. About 1930 it was found that these stains could be dissolved in organic solvents that caused but

—Courtesy Industrial Finishing.
Spraying cedar chests. Note the pendant conveyor and the canopy exhaust.

little grain raising, penetrated better, and dried faster than the water solutions.

Not all furniture is stained; some of it is bleached. Much of today's bleaching is done with concentrated hydrogen peroxide.

Enamel

If furniture is to be finished with enamel, the same principles apply as when clear finishes are used. The same lacquers, low-temperature baking urea-formaldehyde varnish, and oleoresinous varnishes are used as vehicles. Stain, of course, is omitted, and fillers are not applied, since open-grain wood is not used as a rule when enamel finish is selected.

Interior Trim

Interior trim is not usually finished before it is installed in a building. Hence, production-line methods using lacquer and baking finishes are not applicable. Air-drying oleoresinous varnish, and enamel made with it, are used. In the refinishing of furniture in the home, air-drying varnish predominates.

Floors may be prefinished, or finished after being laid. Twenty-five years ago, most jobs were finished with oleoresinous or shellac varnish, with a final dressing of wax. Lacquer is also a suitable finish for floors, while another finish that many people favor is the penetrating type, a thin oleoresinous varnish.

Exterior Paint

For a few hundred years, the orthodox high-grade exterior white paint was made with raw or boiled linseed oil and white lead, and this type of finish is still preferred by some people. But in the past 25 years we have learned how to make better paint. In this, we have been helped by the development of new pigments, notably titanium dioxide. First we learned that mixtures of pigments improved the paint. They control the rate of chalking, do not retain so much dirt, repel mildew, and resist cracking. Next we learned that heat-treatment of the oil also improved the paint. Heat-treated oils do not penetrate the wood excessively and the paint retains its original ratio of pigment and vehicle; they impart more flow to the paint and so eliminate brush marks, and the paint presents a smoother, uniformly thick film to the weather.

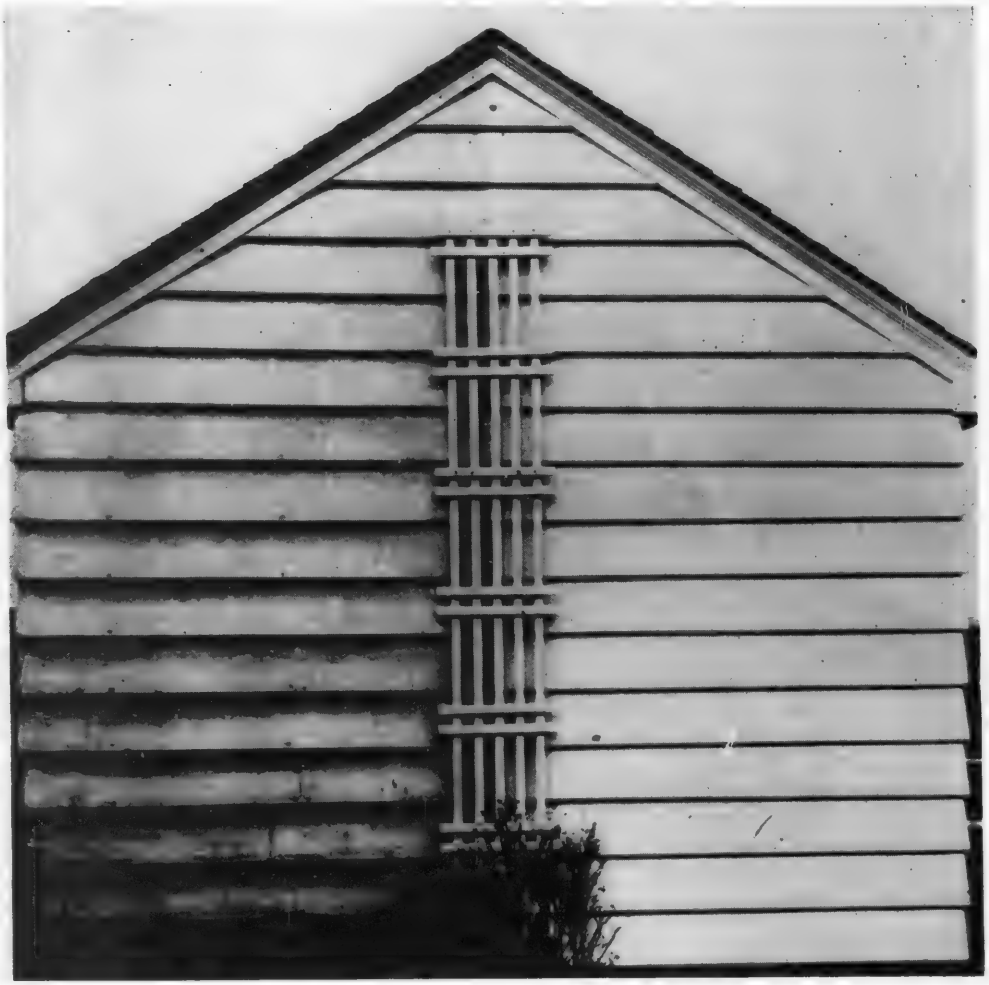
Trim and trellis paints differ from regular exterior paint in that they are designed for better color retention. Such paints have a greater tendency to crack and scale, but most people are willing to sacrifice this property for the color retention. The alkyd varnishes and many improved light-fast pigments make today's trim and trellis paints much better than those of 25 years ago. This paint is also recommended for lawn furniture.

Miscellaneous Articles

Miscellaneous articles are finished with much the same materials used on furniture. But sometimes a very simple finish, like stain and wax is used, as on smokers' pipes. Lacquer is widely used on tool handles, sporting goods, and toys. Pigments used in toy finishes and nursery furniture must be non-toxic.

Violin Varnish

Every few years we see accounts in the newspapers that someone has discovered the violin-finishing secret of the old masters. Usually the



—Courtesy E. I. du Pont de Nemours & Co.

Single-pigment paint vs. multipigment paint after 1½ years' exposure. *Left,* basic carbonate of lead in linseed oil; *right,* mixture of titanium-magnesium, leaded zinc oxide, and basic carbonate of lead in linseed oil.

discoverers do not tell what they found. The most recent book on the subject is by Joseph Michelman of Cincinnati. Michelman took into account the raw materials available in 1550, the approximate beginning of the golden era of violin making. He states that rosin, linseed oil and turpentine, potash, alum, copperas, and madder were known at that time. He succeeded in duplicating the red, orange and brown appearances of the old violins with varnishes made with these ingredients. First, he prepared metallic rosinates, dissolved these in turpentine, and then added the oil. All that remains now is for owners of old violins to donate a speck of varnish from their instruments for confirmatory tests. Michelman believes that the old masters impregnated the wood with linseed oil prior to the varnishing, and this had an influence on the tone of the violin. The varnish was mainly for beauty and protection. Modern lacquers could serve the purpose of the varnish, but additional research by physicists is necessary if we want to replace slow-drying linseed oil for the impregnation.

Application of Finishes

Methods of application have played a big part in promoting the use of paint. The brush has practically no place in industrial finishing, the bulk of which is done with the spray gun. Other methods include dipping, flowing, roller coating, knifing, tumbling, centrifuging, and mopping. Conveyor systems and drying ovens also have a big part in the business. These modern devices have been instrumental in developing finishes that preserve and enhance the beauty of wood the friend of man.

The spray gun is also making considerable headway in maintenance painting of buildings. Spray guns can be adjusted to give narrow patterns, so that the trim of a house can be painted as easily as the siding.

In the last 25 to 50 years, the paint industry has adopted many new materials, such as phenolic, urea-formaldehyde, melamine and alkyd resin varnishes, and cellulosic lacquer for finishes for wood. Research is adding new compositions to the list right along and the future will see even better finishes than those we are now using. The beauty of wood deserves the best.

FOREST PRODUCTS RESEARCH SOCIETY

Characteristics and Related Toxicity of Hydrocarbon Oils

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Research conducted for the past ten or more years, in an attempt to determine causes underlying the toxicity of certain hydrocarbon oils, has led to the development of controls which may be employed in producing toxic hydrocarbon oils from any source of hydrocarbon material. It has further determined that the presence of aromatic hydrocarbons and an established relation between the specific gravity-boiling point ratio of hydrocarbon oils may be employed as a means of predicting their toxicity toward fungi.

THE distillate of high-temperature coal tar has been used for more than 100 years in wood preservation. However, prior to the advent of research which was begun about ten years ago[1], the literature seems to contain little information concerning the real reasons underlying the toxicity of coal-tar creosote toward wood-destroying fungi. Bateman[2] and several others had made a few preliminary studies in the past, in order to develop a theory on the mechanism of the protection of wood by preservatives.

Over the years, the term "creosote" has come to mean that portion of the distillate of high-temperature coal tar falling within a certain approximate range of boiling points and commonly used for preserving wood[3]. In the beginning it was gradually found from actual experience that creosote was a good wood preservative and, without the necessity or benefit of any exhaustive study of its physical and chemical characteristics, it was accepted as such.

With the development of laboratory test methods for determining the toxicity of various materials which may be used as wood preservatives[4], and with the accumulation of test-plot and service data, the wood-preserving industry has demonstrated that the distillate of high-temperature coal tar is not only toxic to wood-destroying organisms, but also possesses other required wood-preserving qualities. In spite of this, however, the reasons underlying the toxic value of coal-tar creosote have been somewhat vague.

Due to the use of different coals, or more particularly to the methods of coking or otherwise processing the coals to produce tar, a wide range of physical and chemical characteristics, as well as a broad range of distillation characteristics, have been demonstrated by the creosotes produced from the various tars. Another factor causing variations in the distillation characteristics is the fluctuating or changing market in by-products, which in turn controls the point to which the distillation is carried in order that the residuum may be soft pitch, hard pitch, or pitch coke. It would appear from toxicity tests, however, that regardless of the variation in distillation pattern of various high-temperature coal-tar distillates, all of them evidence reasonably satisfactory toxicity. Therefore, the specifications covering creosote oil, as originally written and as they appear today, are very broad so as to admit any natural run distillate of high-temperature coal tar. Specifications, however, depend primarily upon that phrase, which appears in all of them, requiring that the source of the creosote be high-temperature coal tar or coke oven tar[5]. In other words, knowing that high-temperature coal-tar distillates were toxic to wood-destroying fungi, but not knowing the reasons underlying their toxicity, the specifications were designed to fit the product.

In the early thirties, a long range project was established in the Research Department of the Southern Wood Preserving Company, for the purpose of investigating various hydrocarbon oils as wood preservatives and of establishing, if possible, the reasons for toxicity or lack of toxicity in these oils. In the initial stages of the work, starting materials were limited to

high-temperature coal-tar distillates, several water-gas-tar distillates of different physical characteristics, and a few highly aromatic petroleum distillates and residuums. A study of the physical and chemical characteristics of individual fractions of these initial samples and subsequent toxicity tests indicated a general relationship between the toxicity and the specific gravity—boiling point relationship of the fractions. It was immediately realized, however, that it would be necessary to obtain other samples exhibiting a wider range of physical and chemical characteristics, in order definitely to determine whether there was a relationship between these characteristics of the fractions and their toxicity. The next step, therefore, was to develop some laboratory method of processing the various samples to a point where they would exhibit different chemical and physical characteristics. This proposed work posed the problem of just what it was desirable to accomplish in the processing to give various types of oils for further experiment and study.

Early in the studies it had become apparent that the presence of aromatic hydrocarbons alone might account for toxicity in hydrocarbon oils. Since the boiling point of aromatic hydrocarbons tends to increase as hydrocarbon chains are added or lengthened (i.e., carbon atoms are increased in the chains) and since the specific gravity of the aromatics tends to decrease in relation to the boiling point as chains are added or lengthened (Table 1), it was evident that, if the processing of the starting material could be properly controlled, it would result in finished products, depending on the control, having varying specific gravity-boiling point relationships for the various fractions. It was found that processing high-temperature coal-tar distillates resulted in very little change in the specific gravity-boiling point relationship of the fractions. On the other hand, changes in water-gas-tar distillates could be accomplished through processing, with the more marked changes occurring in those samples showing the lower specific gravity with relation to boiling points. This was to be expected, since the processing was primarily designed to shorten the side-chain structure of the aromatics. In using the highly aromatic petroleums which exhibited little or no toxicity (within the limits of acceptable values) it was possible, by controlling the process, to produce oils showing a very wide range of gravity-boiling point relationship.

High-temperature coal-tar creosote is a hydrocarbon oil containing a high percentage of aromatic compounds, some olefins and saturates, varying percentages of tar acids and bases, and percentages of a number of various compounds of complex chemical nature. Although it has been shown that many of the identified components of coal-tar creosote have toxic properties, as for example the tar acids, it has also been shown that high-temperature coal-tar creosote, from which the tar acids have been removed, will continue to possess toxic properties[6].

Further, it has been shown that certain water-gas-tar creosotes have toxic properties equivalent to the best coal-tar creosotes, while other water-gas-tar creosotes show little toxicity to-

TABLE 1.—BOILING POINT-SPECIFIC GRAVITY RELATION OF AROMATIC HYDROCARBONS

Name	Formula	Carbons in Chains	B. P. °C	Sp. Gr.	B. P./Sp. Gr. Factor*
Benzene Series					
Benzene	C_6H_6	---	80.1	0.879	91.0
Toluene	$C_6H_5CH_3$	1	110.8	0.866	127.9
Ethyl Benzene	$C_6H_5C_2H_5$	2	136.2	0.867	157.1
Ortho-dimethylbensene	$C_6H_4(CH_3)_2$	2	144.0	0.881	163.5
Propyl Benzene (n)	$C_6H_5CH(CH_3)_2$	3	159.5	0.862	185.1
Trimethyl Benzene (1,2,3)	$C_6H_3(CH_3)_3$	3	176.1	0.894	195.8
Diethyl Benzene (o)	$C_6H_4(C_2H_5)_2$	4	176.5	0.881	200.3
Tetramethyl Benzene (1,2,4,5)	$C_6H_2(CH_3)_4$	4	175.0	0.872	200.7
Butyl Benzene (n)	$C_6H_5C_4H_9$	4	183.1	0.863	212.3
Diethyl Toluene (3,5)	$(C_2H_5)_2C_6H_3CH_3$	5	199.0	0.879	226.4
Triethyl Benzene (1,3,5)	$C_6H_3(C_2H_5)_3$	6	215.0	0.861	249.7
Diphenyl	$C_6H_5C_6H_5$	2	254.9	0.992	256.9
Naphthalene Series					
Naphthalene	$C_{10}H_8$	---	218.0	1.152	189.20
Methyl Naphthalene (b)	$C_{10}H_7CH_3$	1	241.5	1.001	240.30
Ethyl Naphthalene (b)	$C_{10}H_7C_2H_5$	2	251.0	1.008	249.00
Dimethyl Naphthalene (1,4)	$C_{10}H_6(CH_3)_2$	2	265.0	1.016	260.80

*Factor determined by dividing B. P. °C by Sp. Gr. and taken as the boiling point-specific gravity relation.

ward wood-destroying fungi. In water-gas-tar, the nitrogenous bases and phenols are absent or nearly so[7]. On the other hand, the percentage of aromatics in water-gas-tar creosote may be as high as in coal-tar creosote.

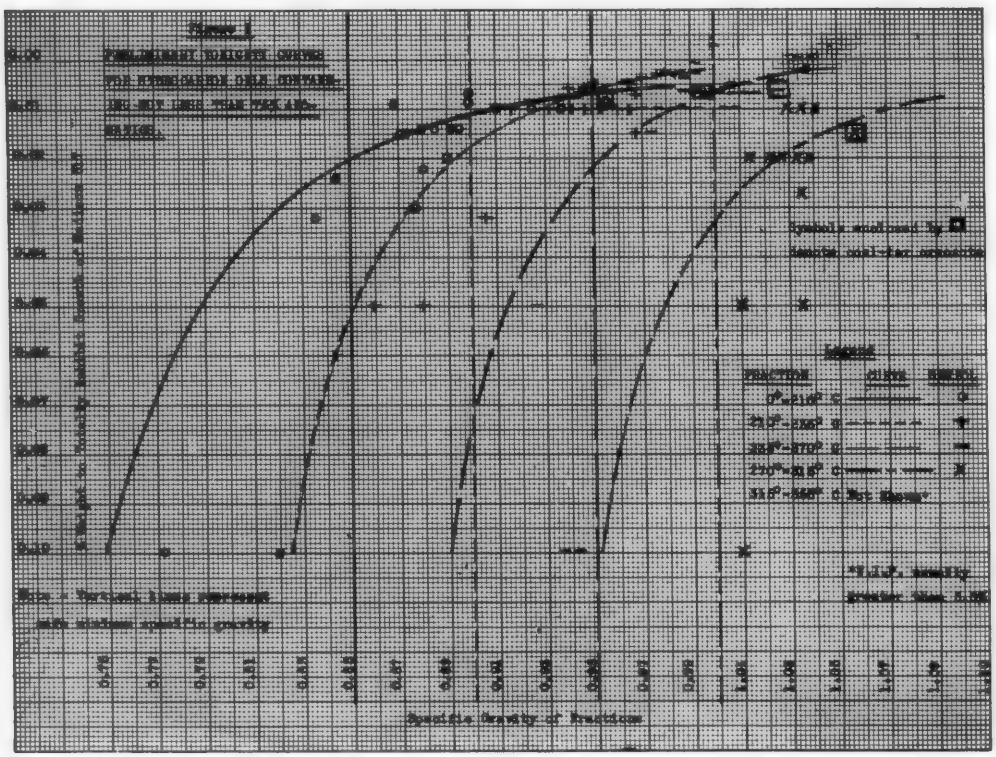
Many petroleum distillates and residuals, particularly those derived from thermal or catalytic cracking processes, may be highly aromatic and yet show little if any toxic properties toward wood-destroying fungi.

Considering the above facts, it seemed certain that aromatic hydrocarbon compounds alone might be responsible for toxicity. However, since all aromatic hydrocarbon mixtures do not show this characteristic, and since some show it in widely varying degrees, it appeared that the character of the aromatic itself might be the determining factor. It was concluded, therefore, that aromatic hydrocarbons having certain chemical and physical properties would be toxic to wood-destroying organisms, and that hydrocarbon oils containing sufficient quantities of these aromatic compounds would also be toxic.

Proceeding along this line of thought, many laboratory process runs were made, in order to produce varying samples for study and also to develop the process and controls which would result in the production of hydrocarbon oils having those physical and chemical characteristics which the toxicity tests indicated were required of a satisfactory creosote wood preservative.

For convenience in making direct comparisons of the materials under study, as against coal-tar creosote, it was decided to employ the ASTM Standard D246–42 (AWPA Standard 11g) fractional cuts rather than to attempt to continue the use of the narrow boiling ranges or separated aromatics. The work which followed has shown this to be a satisfactory procedure and has made possible the setting up of a rather simple method of analysis. This is of great advantage in that wood preservatives are subject to frequent field inspections to determine their value.

Since the studies were to involve a determination of the aromatic content of the samples,



a new method developed at the Central Experiment Station, U. S. Bureau of Mines, Pittsburgh, Pennsylvania[8], was employed to give a sufficiently accurate determination of olefins, aromatics, and saturates.

As the analyses were made of the samples, prepared through the developed process controls, and as the toxic values of these samples were determined and studied, it became more and more apparent that aromatic content and specific gravity-boiling point relation of the fractions under study were definite factors connected with the toxicity of hydrocarbon oils. Specific gravity-boiling point relations of the fractions were plotted against their determined toxicities and gradually curves were evolved from which very definite process controls could be determined for producing a product having acceptable toxicity as a wood preservative. The controls establishing toxicity were those governing the specific gravity of the fractions and the percentage of aromatics in the fractions, as well as in the whole oil, and were as follows:

Fractions	*Specific Gravity (ASTM D369–33)*	
0°–210° C	Minimum	0.85
210°–235° C	"	0.90
235°–270° C	"	0.95
270°–315° C	"	1.00
315°–355° C	"	1.05

Fractions	*Aromatics*			
0°–210° C	Minimum	75%	Preferred	80%
210°–235° C	"	75%	"	85%
235°–270° C	"	75%	"	90%
270°–315° C	"	75%	"	90%
315°–355° C	"	75%	"	90%

When petroleum hydrocarbons were processed so as to obtain the required specific gravity of the fractions, it was found, more often than not, that the percentage of aromatics in the fractions exceeded the minimums listed above, and usually met the preferred percentages.

In a further attempt to prove that the toxicity of aromatic hydrocarbon mixtures is related to aromatic structure, petroleum aromatic mixtures containing olefins and saturates were selected from those materials having relatively low specific gravity in comparison to their boiling range. The fractional parts, as well as a whole sample of these materials, were tested for toxic value by the agar-flask method[9] at the Forest Products Laboratory in Madison, Wisconsin. These materials were found to show potential toxicity, but only to the extent that more than ten percent of the whole sample was required to produce total inhibition; of the fractional parts, the normal growth of fungus at five percent ranged from one to 23 percent. The same samples, when processed to establish a relatively higher specific gravity for each specified boiling range, showed that only about 0.10 percent was required to produce total inhibition to the growth of fungus; of the fractional parts, the quantity required to produce total inhibition ranged from 0.006 to 0.02 percent. These latter values are equivalent to those of the corresponding fractions of coal-tar creosote.

A continued study of aromatic hydrocarbon mixtures obtained from coal tars, water-gas tars, and petroleum residuals (processed and unprocessed), as well as of some pure aromatic compounds, indicated that toxicity of these materials, as determined by the agar-flask method, is definitely related to the boiling point-specific gravity relation of the materials. It also indicated that the boiling point-specific gravity relation is a function of the carbon atoms in the side chains attached to the ring structure.

In the case of those aromatic derivatives containing oxygen, nitrogen, sulphur, or hydroxy radicals, the boiling point-specific gravity relation may also be a function of the atom or radical attached to the ring structure. This is well illustrated by comparing phenol (C_6H_5OH — BP 181.4° C. — Sp. Gr. 1.071 — Factor 169.3) and m-dihydroxy benzene, ($C_6H_4(OH)_2$ — BP 276.5° C. — Sp. Gr. 1.272 — Factor 217.4).

It does not appear, however, that the presence of oxygen, nitrogen, sulphur, or the hydroxy radical in the aromatic structure is necessary to give toxicity toward wood-destroying organisms. It has been shown, moreover, that the effect of an individual group on the toxicity of an aromatic may be to increase toxicity or to have a marked depressant effect on toxicity[9]. In any event, the presence of such groups in coal-tar distillates will account for the higher specific gravity within a stated boiling range than will be found in the same boiling range of a petroleum creosote. (Table 2) This results from the fact that the petroleum

TABLE 2.—ORGANIC RING SYSTEM DERIVATIVES WHICH AFFECT BOILING POINT-SPECIFIC GRAVITY RELATIONSHIP OF HYDROCARBON OILS

(Some or All of These May Be Found in Coal Tar)

Name	Formula	Carbons in Chains	B. P. °C	Sp. Gr.	B. P./Sp. Gr. Factor*
Thiophene	C_4H_4S	---	84.1	1.070	78.5
Pyridene	C_5H_5N	---	115.0	0.978	117.6
Pyrrole	C_4H_4NH	---	133.0	1.077	123.5
a—Picoline	$C_5H_4NC(CH_3)$	1	128.8	0.950	135.6
Thiophenol	C_6H_5SH	---	168.5	1.074	156.9
Coumarone	C_8H_6O	---	173.5	1.078	160.9
Phenol	C_6H_5OH	---	181.4	1.071	169.3
Dihydroxy Benzene (o)	$C_6H_4(OH)_2$	---	242.5	1.344	180.4
Cresol (o)	$C_6H_4(CH_3)OH$	1	191.0	1.052	181.6
Cresol (p)	$C_6H_4(CH_3)OH$	1	202.0	1.039	194.4
Cresol (m)	$C_6H_4(CH_3)OH$	1	203.0	1.039	194.4
Dihydroxy Benzene (m)	$C_6H_4(OH)_2$	---	276.5	1.272	217.4
Quinoline	C_9H_7N	---	239.5	1.081	222.4
a—Naphthol	$C_{10}H_7OH$	---	279.0	1.224	227.9
b—Naphthol	$C_{10}H_7OH$	---	294.0	1.217	241.5

*Factor determined by dividing B. P. °C by Sp. Gr. and taken as the boiling point-specific gravity relation.

creosote is composed almost entirely of aromatics containing only carbon and hydrogen. Reference to the curves shown in Figure 1 will show that in the same boiling range the fractions from coal-tar creosote exhibit the higher specific gravity, but that many of the lower density petroleum creosote fractions show greater toxic value in the same boiling range.

It has been pointed out that hydrocarbon oils containing a minimum of 75 percent aromatics and having certain minimum specific gravity within a given boiling range will exhibit satisfactory preservative value as indicated by the agar-flask method employing fungus Madison 517. Based on studies and results secured from several hundred samples, prepared in accordance with the proper process controls, it appears that the percent of sample by weight, which will totally inhibit the growth of Madison 517 when employing the agar-flask method, will be usually not more than the following indicated values for each fraction and specific gravity of that fraction.

Fraction	Specific Gravity					
	0.85–0.90	0.90–0.95	0.95–1.00	1.00–1.05	1.05–1.10	1.10–1.15
	Percent by weight required to totally inhibit growth of fungus—(agar-flask method)					
0°–210° C	0.05%	0.04%	0.02%	------	------	------
210°–235° C	------	0.04%	0.02%	0.01%	------	------
235°–270° C	------	------	0.20%	0.05%	0.01%	------
270°–315° C	------	------	------	1.00%	0.50%	0.05%
315°–355° C	Usually > 5% unless specific gravity exceeds 1.100					

Toxic values such as these are extremely satisfactory for hydrocarbon oils to be used as wood preservatives, provided, of course, that the permanency of toxicity is satisfactory. That, however, is not a part of the discussion at the moment.

This report is of a preliminary nature only, and makes no attempt to cover the full field of the studies. When the accumulated data is fully analyzed and correlated, a more revealing report will be presented to the wood-preserving industry.

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Discussion

Prof. Frank H. Kaufert (Division of Forestry, University of Minnesota): On reading this paper, one cannot help but be impressed by the amount of work that has been done and compressed into this concise, often too concise, report. The preparation of samples used as the basis for the study alone constituted a task of real proportions.

It is evident from this study that hydrocarbon oils prepared under controlled conditions and having prescribed specific gravity—boiling point limits possess toxicity values comparable to and often superior to the toxicity of coal-tar creosotes. The significance of these results, as compared to the results on coal-tar creosote, are difficult to evaluate because we know so little about coal-tar creosote. If the significance of the toxic and nontoxic constituents of coal-tar creosote in determining effectiveness as a wood preservative were less debatable and more clearly defined, the author would no doubt have had a simpler task of pointing out the significance of the toxicity values obtained in this study.

The author emphasizes that this is a preliminary report and limited to a study of specific gravity—boiling point—laboratory toxicity relationships, but that some data on the value of these hydrocarbon oils as wood preservatives are available and are being evaluated. Interesting and significant as the present paper is, it is certain that future reports will be of even greater interest, because they will show whether these oils are another example of materials with great potential but little actual wood preserving value, or whether their promise as indicated by laboratory toxicity values and promising physical properties is borne out. It is apparent that we are still too much in the dark on the whole question of laboratory evaluation of wood preservatives to say conclusively, "This material or mixture of materials has the desired toxicity, the necessary low volatility, and the resistance to leaching that is needed, therefore it must be a good preservative." The author of this paper is as cognizant of this as the commentor, and he has wisely refrained from predictions in this paper.

However, whatever the results of further tests may show as to the wood-preserving effectiveness of this interesting material, there is real significance in the fact that here apparently is evidence that potentially valuable preservatives of desired specific gravity, boiling point, and toxicity can be prepared from petroleum, and that if such products have the desired wood-preserving properties they can be reproduced. The importance of this should be apparent to everyone who has worked with coal-tar creosote.

Another important point, in my opinion, is that in these hydrocarbon oils we have mixtures of a number of chemicals, as yet possibly largely unidentified, but present in amounts that probably also can be duplicated. We now have several organic and metallo-organic preservatives that appear to be sufficiently effective against a wide range of organisms to protect wood from the tremendous number of wood-rotting fungi that inhabit the soil. These are the exceptions, and anyone who has worked with fungi and knows the variation in tolerance of chemicals that they can exhibit will recognize the value of mixtures of toxic ingredients.

The author of this paper and the company he represents are to be congratulated on the continuity of the effort that has gone into these studies and they may be assured that everyone present and the entire wood preservation industry will look forward to further reports on these hydrocarbon oils.

Mr. R. H. Bescher (Koppers Company, Inc.): If a coal-tar creosote from which certain chemicals or narrow fractions have been removed meets, upon evaluation, the minimum requirements outlined in your paper, would you consider this creosote a satisfactory wood-preserving oil?

Mr. Vaughan: Yes. Any hydrocarbon oil meeting the minimum requirements for aromatic content and specific gravity of the AWPA fractions would show acceptable toxicity and wood-protecting characteristics, as outlined in my paper.

Mr. C. M. Sporley (Valentine Clark Corporation): In tests you have made, have you been able to determine whether the toxicity of present-day creosotes has been seriously affected by the removal of some of the components of the oil during manufacturing?

Mr. Vaughan: The present-day creosotes which we have employed in connection with this work and which have been tested for toxicity have been found to exhibit a satisfactory degree of toxicity when tested by the agar-flask method against fungus Madison No. 517.

Mr. E. A. Behr (Chapman Chemical Company): What were the sources of the petroleum oils which you used, that is, were they Louisiana, Arkansas, East Texas, California, or Pennsylvania materials?

Mr. Vaughan: We did not actually employ the crude oils in this work. We did, however, use residuals from thermal or catalytic cracking units and these residuals represented oils produced from practically all of the major oil fields with the exception of the Pennsylvania fields.

Mr. C. H. Morton (C. B. and Q. Timber Preservation Plant): Did you find that the materials, which you are comparing to coal-tar creosote, had low specific gravities?

Mr. Vaughan: The specific gravities of most of these materials were less than one. We found, however, that these materials had high toxicity and the low specific gravity does not appear to be of any disadvantage. In handling the materials in the plant, it was actually found that it was easier to separate water from them since it was only necessary to let the water settle to the bottom of the tank and then draw it off.

Mr. Morton: In June 1940, the School of Forestry, Engineering Experiment Station, Oregon State College at Corvallis published Bulletin Series No. 13, "Oil-Tar Creosote for Wood Preservation", by Glenn Voorhies, then Assistant Professor of Wood Products. This was a research project of the School of Forestry with the cooperation of the Portland Gas and Coke Co. Voorhies made quite a study of the coal-tar creosote, water-gas-tar creosote, and oil-tar creosote, going through the whole bag of tricks involving conformance to AWPA specifications, pathological study, leaching tests, and treatment with respect to penetration. Briefly, the conclusions are:

1. Tar acids and tar bases in creosote oil are not essential to a long lasting preservative. Oil-tar creosote contains very slight amounts of both.

2. No significant difference noted in comparable leaching tests on oil-tar creosote and coal-tar creosote.

3. Oil-tar creosoted blocks superior to coal-tar creosoted blocks on basis of Kolle flask tests against *Lenzites trabea.*

4. Initial toxicity of the coal-tar creosote tested appears somewhat higher than oil-tar creosote. However, it is believed that the higher concentrations used in commercial treatments would give adequate protection for many years.

5. Oil-tar creosote possesses good penetrating qualities, and its viscosity was found to be lower than that of the coal-tar creosote tested.

6. Oil-tar creosote possesses all the requirements of APWA specification for Grade 1 creosote with the exception of guaranty of coal-tar origin and a specific gravity difference of 0.01.

7. Oil-tar creosote has greater resistance to volatilization than coal-tar creosote.

8. High temperatures used in cracking this California type petroleum oil residium produces a tar containing a very high percentage of aromatic hydrocarbons which are more toxic than phenols.

9. Portland Gas and Coke Co. has (1940) potential annual producing capacity of 4 to 5 million gallons of oil-tar creosote.

Voorhies is no longer affiliated with the college, and apparently this study has been dropped, at least at the college and at the Gas and Coke Co.

The Use of Treated Car Lumber by the Railroads

P. D. Brentlinger
Forester, The Pennsylvania Railroad, Philadelphia, Penna.

The preservative treatment of car lumber by the railroads is a subject that has been more or less active for many years.

Scarcity of materials, conservation of natural resources and the anticipated economy of treated car lumber have been the principal reasons for the adoption of programs for treated car lumber by the railroads.

THE use of wood as a material for construction has been limited in many instances because of its susceptibility to destruction by fungi. These low forms of plant life, which are unable to synthesize their food from the elements, depend upon the cellulose and lignin already produced by trees for their food supply. Through enzymatic action the root-like mycelium of the fungus penetrates the wood cells and slowly destroys them. The strength properties are gradually reduced until the wood is no longer fit for the structural purpose intended.

To combat this destructive process the wood-preserving industry was born. Various oils and salts applied to wood were found to be toxic to fungi. At first these preservatives were applied as coatings, but methods of penetrating wood were evolved which greatly increased the protection from fungus attack and for a greater period of time.

In addition to destruction through decay, wood is also destroyed by mechanical wear. These two factors go hand in hand and, under certain conditions, it is often difficult to determine which is more important. In fact, it may be that either one may be responsible for the other or at least complement it.

When preservative treatment of railroad cross ties was first advocated, there were many arguments against it, based on the contention that it would not be economical to make the wood decay resistant when the mechanical life did not warrant it. The general use today of treated cross ties is sufficient evidence that treatment extended the life of cross ties and was found to be economical. As a general statement, it may be said that treatment has about doubled the present cost of the cross tie, but tripled its average life.

Early Use of Treated Car Lumber

The subject of preservative treatment of material for car construction was introduced to the American Wood-Preservers' Association in 1913. In 1911 one railroad had used approximately 1,340,000 board feet of pressure-creosoted Douglas-fir for the construction of floors and sills in stock cars, and felt sure that the installation would prove successful. Considerable interest was aroused at the association meeting and the appointment of a committee was recommended to study the entire subject of treated lumber for car construction.

The first committee report was made in 1919, based on information received from 88 questionnaires representing 75 percent of the major railroads. It revealed that up to this date only one railroad had used any pressure-treated lumber in car construction, although many had used creosote or other preservatives as coatings where wooden members were in contact.

Causes of Failure in Car Lumber

One of the first problems was, and is, to determine why lumber is renewed in railroad cars. Here again the question of mechanical or decay failure exists and still without perfect agreement.

In 1922, one railroad made an analysis of cause for failure of various wooden members of stock, box, coal, ballast, flat, refrigerator,

and tank cars and arrived at the following conclusions:

Description of Part	Causes for Failure Decay	Other
Draft timbers	0.0%	100.0%
End sills	34.4	65.6
Deadwoods	7.4	92.6
Long sills	68.0	32.0
Subsills	26.2	73.8
End posts	32.4	67.6
Coal car sides	80.1	19.9
Running boards	97.3	2.7
Roofing	100.0	-----
Siding	89.5	10.5
Lining	89.1	10.9
Decking	95.4	4.6
Grain strips	96.5	3.5
Average	82.3%	17.7%

An independent survey, made by the Mechanical Department of another railroad handling all kinds of equipment, reported in 1925 as follows:

Description of Part	Causes for Failure Decay	Other	
Draft timbers	0.0%	100.0%	
End sills	25.0	75.0	
Deadwood	7.4	92.6	
Longitudinal sills	68.0	32.0	
Subsills—Nailing sills*	100.0	0.0	
End posts	0.0	100.0	Breakage
Coal car sides	50.0	50.0	
Running boards	97.3	2.7	
Roofing	100.0	0.0	
Siding	10.0	90.0	
Lining	wears out	-----	
Decking	50.0	50.0	
Grain strips	last life of car		

*Steel Underframe Cars.

Obviously there are some differences between the two tables. Probably there ought to be more.

Each user of car lumber may have his own opinion of the reason for failures, but it should be remembered that many failures are listed as mechanical, even though the lumber was first rendered unsound through decay. Early stages of decay are not easily recognized but cause softening of fibers and reduction of ability to withstand shocks.

Some items of car construction are more susceptible to failure because of decay due to exposure, while others are subjected to greater physical stress. Running boards, for example, do not receive severe mechanical wear but are continually exposed to the weather with every opportunity of intermittent wetting which promotes decay. On the other hand, the lining inside of a box car is fairly well protected from the weather, but may receive hard mechanical wear depending on the type of material being transported. Here it is also necessary to recognize that the type of service for which a car is employed might well determine the kind of failures to be expected. Several railroads have decided that wood flat-car decking and underframing were removed because of mechanical wear only and returned to the use of untreated flooring after having tried creosoted material. Other railroads are convinced that decay is the major cause of renewals on the same type cars.

Several railroads using creosote treatment for flat-car decks and underframing show impressive service records and claim that creosote treatment not only protected the wood from decay but also increased its resistance to mechanical abrasion.

It is entirely possible that type of service is responsible for these differing experiences, and therefore each user must determine his own needs by accurate observations. This attitude was adopted by the Association of American Railroads quite a few years ago.

Service Life of Wood Car Parts

Approaching the problem from another direction, the Committee on Car Construction of the American Wood Preservers' Association sent a questionnaire to Mechanical Superintendents of the various railroads, requesting information on the average life of untreated wood car parts. This was about 1922. Although there were many differences, the compilation was reported as follows:

Description of Part	Average Life, Untreated
Stock-car decking	2 to 6 years
Stock-car sills	5 to 8 "
Stock-car roofing	4 to 6 "
Stock-car side posts	4 to 6 "
Stock-car end posts	6 to 8 "
Refrigerator sills	4 to 5 "
Refrigerator sub flooring	3 to 4 "
Flat-car decking	6 to 8 "
Flat-car sills	8 to 10 "
Box-car sills	6 to 10 "

With at least some agreement on the average life of untreated parts, the next step, of course, is to determine the average life of treated material. Service records are the actual proof of whether or not a practice is desirable. With respect to car lumber, it is a very difficult task to keep such records because cars are generally repaired at numerous points on any one railroad and very frequently on foreign railroads as well. Gradually service records on individual installations are being reported which, in time, may be accumulated to give an average figure on the life of treated car items. Two railroads show records of creosoted flat-car decking lasting 12 to 15 years. Another railroad has re-

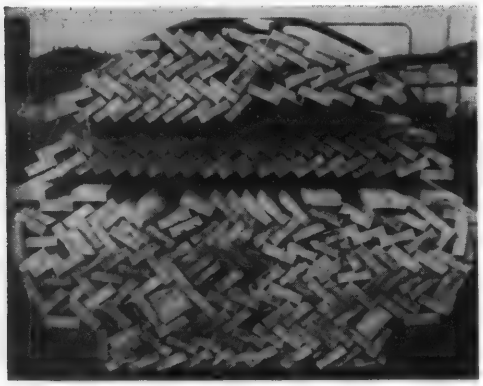

Fig. 1.—Running boards trammed for chemical salt treatment. Note herringbone method of loading to allow maximum exposure of surfaces.

ported salt-treated sheathing in service over 12 years without indication of decay. Many railroads have records of creosoted stock-car decking and underframing which has lasted or is expected to last over 20 years. The indications are that treatment will prove as economical for materials of car construction as it has for cross ties.

The logical approach to the preservative treatment of car lumber has been to start with those items which likely fail primarily from decay, and to extend the program to other items as greater knowledge and experience is obtained.

Factors Affecting Choice of Preservative

Many problems have confronted the car builder, one of which has been the choice of preservative to use. Any of the conventional preservatives could be used on the following parts without danger of contamination to the lading:

Underframing	All types of cars
End posts	All types of cars
Flooring	Stock cars
Flooring	Flat cars
Flooring	Coal cars
Roofing	Stock cars
Sub flooring	Refrigerator cars

Creosote, which has been used on all these materials, cannot be used for some box or refrigerator car parts. One railroad was sued for damage to a carload of flour carried in a box car which had been used previously for transporting a load of creosoted cross ties. The refrigerator-car companies have not used creosote, because of danger from odor contamination to merchandise such as butter, cheese, and other foods.

All railroads have a certain color scheme which they maintain on their rolling stock and could not paint over creosote.

Salt preservatives, like zinc chloride, give a clean, paintable surface and have been found favorable for application to many of the items from which creosote is prohibited. However, the ever-present problem of leaching in wet locations, which is greatly reduced when salt-treated wood is painted, and the extra time and cost required in drying the lumber after treatment have made many car builders hesitant to use preservatives of this type.

The use of chemical salt preservatives in car lumber creates questions in the minds of the uninformed, with reference to corrosion, effect on lading, and, in the case of stock cars, the effects on stock, should they happen to chew on the wood. The following corrosion tables show the effect of wood preservatives in southern yellow pine and Douglas-fir on steel, iron and brass:

SOUTHERN YELLOW PINE

Reagent	Retention Lb./cu. ft.	Depth of pitting in thousandths of an inch Steel	Galvanized Iron	Brass
CZC	1.40	2.04	.755	.261
$ZnCl_2$	1.45	3.34	.578	.337
Tanalith U	.60	1.60	.815	.129
Z.M.A.	.45	3.77	.790	.334
Creosote	7.3	.332	.448	.244
Untreated	X	1.84	.317	.187

DOUGLAS FIR

Reagent	Retention Lb./cu. ft.	Depth of pitting in thousandths of an inch Steel	Galvanized Iron	Brass
CZC	1.90	2.74	.456	.185
$ZnCl_2$	2.05	5.39	.592	.328
Tanalith U	.35	.925	.510	.190
Z.M.A.	.35	2.21	.798	.545
Creosote	9.4	.145	.255	.215
Untreated	X	.922	.498	.244

Tests prove that lading of any description carried by the railroads is not affected by properly salt-treated car lumber. Nor are cattle, hogs or sheep affected by licking, or chewing, salt-treated lumber.

A general preservative which could be used for any part of any car would have to be toxic to fungi but not to animals, as well as odorless, tasteless, colorless, clean, paintable, easily han-

dled, economically available in large quantities, stable after injection into the wood and quickly usable after treatment. The ideal preservative is yet to be found, but while striving for perfection, the materials at hand can be used to good advantage with proper planning.

Planning the Use of Treated Car Lumber

This topic of proper planning is in itself a weighty subject.

Consider the distribution of car lumber, not only with respect to the various treatments for various parts, but also in view of the different car-building programs for:

1. New cars
2. Rebuilt cars
3. Heavy repairs at principal shops
4. Minor repairs at small outlying shops
5. Repair of cars on foreign lines
   a. Heavy repairs as in 3
   b. Minor repairs as in 4

Recommendation was made in 1925 that small treating plants be erected at each major car shop, with arrangements for distribution of treated material to smaller outlying shops. By

Fig. 2.—Treated car lumber being removed from cylinder.

this means lumber could be fabricated as needed and treated immediately. Perhaps this was a fine suggestion, but it would have taken business away from the wood-preserving companies and further complicated the numerous activities of the railroads. Regardless of the reason, few railroads have treating plants at their car shops today, but, instead, route the fabricated car parts to the wood-preserving companies for treatment and return, or for storage, as the situation requires. Many items of car construction, such as running boards, flooring, lining, roofing, sheathing, etc., can be purchased already run to pattern, and sent directly from the producer to the treating plant. Furthermore, most wood-preserving plants are equipped to fabricate many items of car construction and can handle rough lumber direct from the producer.

It is advisable to have treated wood car parts in storage, ready for use, because the dates of car repair programs are often uncertain and, when scheduled, may leave very little time for the preservative preparation of lumber, especially that treated with salt preservatives which require either air seasoning or kiln drying before using.

Under emergency conditions it has been necessary, and probably will continue to be necessary, to use untreated lumber in some cases, even though a program has been set up for the use of treated material. With more planning and preparation this volume could be reduced.

The storage of treated car material has another advantage. If the shops become over supplied with a particular item, there is little danger of deterioration while in stock. There have been instances where considerable quantities of untreated lumber have been lost in storage because it decayed before it was used.

Wood Versus Steel in Railroad-car Construction

The car-lumber requirements of the railroads are constantly undergoing changes. Cars of different design are being built and construction

Fig. 3.—Tram load of treated running boards before stacking for drying on yard. Treated lumber stored for air seasoning.

Fig. 4.—Creosoted wooden underframing supports in place and partially installed creosote-treated stock-car floor.

is being changed on older cars as they are repaired. Steel has replaced wood for many underframe items and in the superstructure as well. However, the changes have not been as radical as the Master Car Builders Association predicted in 1922, when they rejected consideration of using treated car lumber because they expected all wooden members to be replaced by steel in a short time, except for refrigerator cars. Again in 1931 the prediction was made that the steel-underframe car with wooden superstructure would closely follow the all-wooden car into obsolescence. Obviously, the wooden superstructure car is still in existence today and probably will continue in use for some time.

Similar to the trends in other construction during the war period, wood was used to replace steel for some parts of new cars and for repairs to old cars. An effort was made by some of the railroads to have treated lumber installed in newly designed cars during this period and, if found satisfactory, increased use of treated wood may be expected.

Potential Market for Treated Lumber

It is practically impossible to calculate with any degree of accuracy what the potential market for treated lumber in car construction is or will be. Using a few figures and considerable imagination, however, some idea may be obtained. The Car Builder's Encyclopedia for 1940 lists the following freight cars in service on the railroads of the United States as of January 1, 1939:

Type of Car	Number	*Board Feet per Car
Box	738,509	3,000
Stock and Poultry	66,425	4,000
Refrigerator	147,187	4,000
Flat	70,688	1,200
Gondola and Hopper	813,592	2,200

*The board feet per car figures were not part of the encyclopedia compilation, but are approximations of the amounts of lumber which several railroads require to be treated under existing specifications. These amounts do not include all wooden parts on these cars and are therefore conservative.

Applying these figures to only one-half the number of box cars and one-fourth the number of gondola and hopper cars in addition to the stock, refrigerator, and flat cars, a total of approximately 2,500,000,000 board feet is obtained. Taking five years as the average life of untreated wood in these cars, 500,000,000 board feet would be the annual requirement for repairs alone. During the five year period, 1942 to 1946, an average of approximately 5,000,000 board feet per year of treated lumber was used in railroad car construction, or about one per cent of the potential amount for repairs alone.

These estimates would indicate that the treatment of car lumber is yet to begin. With respect to many railroads this is true, while others are using treated material experimentally, and still others have standardized on the use of treated lumber for several types of cars and for parts of other types.

Specification Requirements

The following specification is an example of the program on one railroad and gives full details as to material, methods of treatment, etc.:

Purpose

This specification provides for the preservative treatment of car lumber and timbers, by pressure processes, in order to increase the resistance of the wood to decay.

Material

Those wooden details in cars designated herein.

Preservative

The preservative shall be creosote or a chemical salt, conforming to the current specifications of the American Wood-Preservers' Association.

General Requirements

1. *Seasoning:* Prior to treatment, all car lumber and timbers shall be seasoned in open stacks in a yard, or by drying in a kiln, or by steaming, until, in the judgment of the Railroad's representative the moisture in the wood will not prevent the injection and proper distribution of the preservative.

2. *Preparation for Treatment:* So far as practicable, all adzing, boring, chamfering, framing, gaining, incising, surfacing, trimming, etc., on car lumber and timbers shall be done prior to treatment.

Incising of Douglas fir, of 3 inch and greater thickness, will provide deeper penetration.

3. *Manner of Treatment:* Any cylinder charge shall be confined to one kind of wood, and, whenever possible, of closely similar sizes, of approximately equal moisture and sapwood content, into which preservative can be injected to approximately the same depth.

Treating operations shall be in accordance with the current American Wood-Preservers' Association standards for the injection of preservatives by pressure processes for the species of wood undergoing treatment.

Creosote treatment shall be by the Empty-Cell Process with Initial Air; the chemical salt treatment by the Full-Cell Process.

At the completion of creosote treatments, any surface coating of unabsorbed oil may, at the discretion of the Railroad's representative, be cleaned by a final steaming at not more than 260° F., for not less than one hour, followed by a vacuum for one-half hour.

4. *Retention of Preservative:* Retention shall be ____ pound of _____, or ____ pounds of Creosote, per cubic foot of wood.

Type of Treatment

Material to be treated with No. 1 Creosote oil to a final retention of ____ pounds per cubic foot and steam-cleaned after treatment:

Deck Bearers
Fillers
Flooring
Floor Supports
Upper Deck

Material to be treated with chemical salt to a final retention of ____ pound per cubic foot and air-dried or kiln-dried after treatment:

Battens
Brake Step Boards
Doors
Fascia
Marking Boards
Purlins
Rails
Roofing
Running Boards
Side Slats

Shipment and Storage

Deck bearers, flooring, lining, roofing, running boards, sheathing, side slats and upper deck flooring will be shipped direct to the treating plant from the point of production.

Battens, brake step boards, doors, extension and latitudinal running boards, fascia, fillers, floor supports, marking boards, purlins, rails and saddles will be fabricated at the shops and shipped to the treating plants.

Salt treated lumber to be stored at the treating plants and after drying to be properly protected against the weather.

Inspection

Facilities: The treating plant operator shall provide, free of charge, suitable facilities and any assistance and equipment necessary for the Inspector to work efficiently.

Sampling: The Railroad Company shall have the right at any time to test the preservative to be used in treating its car lumber or timbers. Samples may be taken from any container in which the preservative is stored or used.

The Railroad's representative shall have the right to examine any of the equipment used on any process or method of treatment at any stage in the treatment.

Warranty

Indemnity: The treating plant operator hereby covenants and agrees to save harmless and indemnify the purchaser against all claims, suits, actions or proceedings, damages, costs, fees, and expenses by reason of alleged infringement of patents, or for patent royalties involved, in consequence of the purchase or the use of the materials and services covered hereby.

Handling

Rough handling is never desirable, therefore, when car lumber and timbers have been prepared by preservative treatment to forestall deterioration by decay, all care must be used to avoid a reduction in serviceability through splitting and breakage resulting from needless rough handling.

Economics of Treated Lumber

The economics of treated lumber for car construction is dependent on so many variables that any single approach may be considered inadequate. But, for the sake of an example, we may take one item, from one type of car, subjected to one general kind of service, namely, the flooring in a stock car:

	Stock Car Flooring Costs	
	Treated	Untreated
1,200 board feet southern yellow pine — $100 per M	$120	$120
Cost of treatment using 8 lbs. per cu. ft. of No. 1 creosote	30	0
Cost of installation of floor	20	20
	$170	$140
Average life—years	20	5
Cost per year	$ 8.50	$ 28.00

These figures are a hypothetical summary of only the most obvious details, and these can be varied considerably. Perhaps a cheaper grade of pine could be used, because heartwood specification is not essential with preservative treatment; or a cheaper species of hardwood that resisted wear better could be substituted for pine, because treatment reduced the decay factor. It might be that, instead of No. 1 creosote, another preservative would prove effective, or maybe a six or ten pound per cubic foot treatment of No. 1 creosote would be better. Cost of installation is partly dependent on labor costs and these can change substantially during the life of a stock car.

Some of the other items of cost are not as evident. Increased insurance for storing creosoted material, for example, or increased cost of transporting materials to and from a treating plant.

There are other savings accruing from longer service life which are not so obvious. Loss of a car from service while being repaired means loss of revenue. Removal of decayed parts often means destruction of good parts in the process. The fewer times a car is repaired during its life-time, the more valuable it is to the owner, from many standpoints.

To summarize the problems of using treated car lumber and the savings to be derived therefrom, reflect on the general picture of railroad experience with treated cross ties during the past 40 years. Few railroad representatives will perfectly agree on (1) the causes for cross-tie renewals, (2) the average life of treated or untreated cross ties, or (3) the methods of treatment or preservatives to be used. But practically all will agree that the treated cross tie is economical to use. Perhaps in future years the same conclusion will be reached with regard to treated car lumber.

Discussion

Mr. R. S. Belcher (The Atchison, Topeka and Santa Fe Railway Company): Mr. Brentlinger's paper has been so well developed and is so complete that there is not much comment I can make, except to say that he has done a very fine job with a rather difficult subject. Some of us oldtimers, who were members of the American Wood Preservers' Association committee on the use of treated car lumber a good many years ago, recall that in some years it was rather difficult to dig up something encouraging on this subject to report to the Association. As Mr. Brentlinger has pointed out, there was a question in the minds of many of those in charge of car construction and repairs, as to whether or not preservative treatment was worthwhile, because it appeared that failure of much of the lumber was due to mechanical wear rather than decay; it was the opinion of many that steel would entirely supplant lumber in freight cars. Yet treatment of car lumber has slowly gained in volume and favor, and a very substantial saving was made on such treated car lumber as was used. For instance, it was reported that one road decked 287 flatcars with creosoted pine in 1928. A record of these cars was kept, and it was determined that the average life of this car decking was about 12½ years—two to three times the service life of untreated pine decking. Mr. Brentlinger has shown in his paper the very considerable saving possible from the use of treated stock car decking. As the labor cost of installation increases, and as the cost of the material used advances, the savings derived from the longer service life of treated car material will be even more worthwhile.

Mr. H. R. Duncan (Chicago, Burlington and Quincy Railroad): We, on the Burlington, have used a considerable quantity of treated lumber in cars, particularly in decks of stock cars and some flat cars and miscellaneous parts of other cars. I have also served as a member and chairman of the American Wood Preservers' Association committee on treated car lumber, and representatives of this committee have attempted to influence the greater use of treated lumber in car construction by working with the A. A. R. Mechanical Division Committee on car design. However, we have never found the car builders or the committee responsible for the design of cars very receptive to the use of treated wood.

A study by the Forest Products Laboratory a number of years ago indicated, very definitely, that there has been a gradual reduction in the amount of lumber used in car construction and an increasing use of steel. While I have no figures available at this time, it is my opinion that this trend has continued and now even less wood is being used in car construction than at the time this study was made.

The designers and maintainers of cars look back at the time they were using large quantities of wood in cars when the cars were of lighter capacity and operated from 20 to 40 m.p.h. Today they are looking for higher capacity pay loads and are thinking in terms of design for probably 40 to 80 m.p.h. Consequently, I don't look forward to greatly increased usage of treated car lumber, but am of the opinion that unless we can do something to make wood more desirable, the use of lumber in car construction will diminish even further.

Mr. A. J. Loom (Northern Pacific Railway Company): I think Mr. Brentlinger has covered his subject very well and that his paper is both timely and good, especially in view of the present vigorous promotion of all-metal construction of railroad cars. With proper preservative treatment I believe wood construction of many of the car-building items listed by Mr. Brentlinger will prove most economical. Obviously, steel must be used for the items requiring greatest strength in modern car construction, but in my opinion it has no superiority to warrant its exclusive use in preference to wood for various other items and for that reason many railroads are continuing to use large quantities of lumber in their car-building programs.

Mr. T. H. Friedlin (New York Central System): The New York Central has on order some new box cars which are being built with metal running boards. The use of metal for such a purpose will decrease the lumber consumption of the railroads; in the particular lot of box cars referred to, it will mean a reduction of about 400,000 board feet of lumber.

Fence Posts: An Untapped Market For the Wood Preserver

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THERE are estimated to be about 6½ million farms in the United States. Although the individual farms vary as to productivity and methods of operation, most of them have a common and persistent problem—that of building and maintaining serviceable fence lines. Generally, the fences consist of woven wire supported by steel, concrete, or wooden posts. Since most fence failures may be traced to the vulnerable posts, the farmers' problem is mainly one of finding a post which is strong and durable and to which the fencing can be securely and easily fastened. The relative merits and disadvantages of steel, concrete, and wood have been discussed many times, and it is probably generally conceded by farmers that the wooden post has the greatest number of desirable characteristics. In fact, the consumers' complaints usually concern the wooden post's main weakness, its variable service life or low resistance to decay.

Recently the Illinois Agricultural Experiment Station conducted a survey of the fence-post situation in the United States. Experts in each state were asked questions regarding the annual wooden post requirements of their farmers, to what extent treated wood was being used for posts, and why farmers were not using more treated posts. Answers indicated that approximately 500 million wooden posts are needed each year. Assuming that the average post is seven feet long, has a 5-inch top diameter, and a volume of one cubic foot, the annual requirements total 500 million cubic feet. The U. S. Forest Service reports that nearly 36 million board feet, or slightly over seven million posts, were treated commercially last year, and the annual average for the past nine years is only 4¾ million posts. These data indicate that the wood preservers treated slightly over one percent of the nation's requirements. This estimate is substantiated by answers in the survey which pointed out that farmers were not buying treated posts in preference to other types, because treated posts were not available.

The problem of supplying farmers in the United States with treated fence posts can be divided into three parts: (1) The raw supply; (2) the facilities, materials, and labor for treating; and (3) the merchandising of the treated product. A fourth phase, the conservation of the nation's wood resource, is also important. Much white oak, for example, that is now being split into posts could be saved for the furniture industry or some other market demanding quality material.

Reforestation and sustained-yield management of existing forest lands is the solution to a larger, sustained supply of material suitable for posts. Management of plantations and young stands generally means that a large volume of post-sized material is available from thinnings.

The solution of the second part of the problem—the facilities, materials, and labor for the treating job—will depend upon the market. With an adequate supply of raw materials and a good market, the wood preserver will solve the mechanics of treating operations.

The third phase—proper merchandising—may well be the most important. Mr. F. A. Linde of the Monsanto Chemical Company, St. Louis, has indicated that a recent survey he made showed less than 40 percent of the farmers in the United States to be familiar with the value of treated wood. This points up the need for a special kind of advertising, to inform the farmer so that he will become interested. Sales

representatives must not only work with state agricultural extension services, forestry departments, and similar agencies, but also with the small lumber yards, feed stores, and particularly with the farmers' own organizations.

Treated posts must be readily available to the farmer, for he, like all of us, takes the path of least resistance. We must not expect him to drive long distances to buy treated posts if he can find a substitute closer to home, even though the substitute is less serviceable. Treated posts should be made available locally —at the small lumber yard, the grain elevator, or the feed store—where the farmer knows the proprietor and where he is accustomed to doing business. The farmer cooperatives are good markets. One company in the South discovered that the development of a program of local merchandising in Iowa increased its post sales several hundred percent.

The treated post must have sales appeal, preferably an appearance that will lead the farmer to believe it will last forever. The major complaint of those marketing posts given "clean treatment" is that the farmer just won't believe the posts will last—if they aren't black or dark brown or highly colored, the posts can't last. Obviously all the 500 million posts cannot be treated with coal-tar distillates. If color is added to some pentachlorphenol solutions, the posts treated with them will have greater sales appeal. Copper naphthenate, for example, imparts a pleasing green color to the wood which gives a post sales appeal.

The question of retail price is much discussed by the farmer. Frequently he feels that pressure-treated posts costing one dollar or more each are too expensive. Obviously the price of treated wooden posts must be in line with competitive steel and concrete. However, the relationship between retail cost and cost per year of service life is not always understood by the farmer or the local retailer. A pressure-treated post that retails for a dollar and will serve for 25 years is much cheaper than a 60-cent post that lasts only ten years. The 25-year post serves at an average annual cost of four cents compared to a 6-cents per year cost for the ten-year post. Besides having a cheaper average annual service cost, the purchaser of the treated post saves the labor needed to replace the post having a shorter service life. The economics of post costs and service life must be made available to local sales personnel as well as to the customer.

The survey revealed that although increased effort has been placed on the programs encouraging home treatment of posts, the farmer at present generally considers home treatment too much trouble and prefers to buy his posts already treated, or use untreated wood.

The subject of farm cooperatives is much discussed currently. Regardless of whether the co-ops are socialistic or capitalistic, or whether they are taxed too lightly or too heavily, the fact remains that a *need* brought them into existence. Unless supplies of durable posts are made available through existing channels to satisfy the current demand, farmers' cooperatives may move into the field and do the job. Cultivation of current sales opportunities will make these same organizations customers—not competitors—for the wood preserver.

The post market is not a war development; it has been in existence for many years. The pinch of scarcity created by decreasing supplies of naturally durable woods has helped to bring the post market into focus in many parts of the country. Opportunity is knocking for the wood preservers! A big fence post market is waiting to be tapped, and the producer that gets there "fustest with the mostest" will be rewarded.

FOREST PRODUCTS RESEARCH SOCIETY

Acid-Proofing of Wood

R. H. Bescher

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The use of wood in chemical industries is being maintained by improving its chemical resistance to destruction by acid and corrosive fumes, by impregnating the wood with phenol formaldehyde or bituminous resins. Processes for impregnating the wood, characteristics of the impregnated wood, and applications are given, also some laboratory data on the resistance to hydrochloric and sulphuric acids.

Introduction

WOOD is one of the oldest building materials. It has been used in almost every conceivable type of structure. Some places it has remained as the most economical, in fact almost the sole material, as in the case of railroad cross ties. In others, its use now almost seems ridiculous—a chimney for our forefather's log cabin. Wood has been used in a large variety of places because of its availability, ease of fabrication, remodeling, and enlarging. It is a commonly used material in the development of new machines, processes, and products.

For this reason, wood has been used to a great extent by the chemical industries. It has a natural resistance to the actions of dilute acids and alkalies, both in the liquid and vapor phases, but continued exposure to the corrosive actions of chemicals causes gradual decomposition. If as a result of chemical action, its life has been short and uneconomical, it has been replaced with either better or more effectively promoted materials. As the cost of replacement increases, both for material and labor, the service life of the product must be increased or it becomes uneconomical.

It is highly probable that cross ties would have been replaced by competitive materials if it were not for the preservative treatment which they receive and which increases the useful life from an average of 7 years to 25 years.

The wood-preserving industry has been pressure-treating wood with preservatives for over 100 years, to prevent its destruction by the attacks of decay, termites, marine borers in salt water, and fire.

Resin Impregnated Wood

Wood is now being pressure impregnated to increase its resistance to chemical attack. This may be done with phenol formaldehyde resin in its water-soluble primary state of polymerization.

While the resin is still water soluble, it is possible to impregnate such resin deeply into the wood by standard wood-treating methods and equipment. Following the impregnation, the wood must be carefully kiln dried and the resin then set under high temperatures. If the wood is set between heated plates in a press, the temperature normally used is about 300° F., requiring several hours time. If the wood is set in a kiln, temperatures employed are usually 200 to 210° F., and the setting requires several days. To obtain the greatest chemical resistance, dimensional stability, and increased hardness, it is necessary to impregnate into wood a weight of resin equal to approximately 30 percent of the weight of the wood.

These resins are relatively expensive, and the kiln drying and setting process is long. The resins as well as the water, when impregnated into the wood, tend to warp and distort it. Therefore, the final milling should be done after treatment and setting of the resin. However, for special cases, the product is still economical.

Bituminous Impregnation

A less expensive method of protecting wood against the attack of chemicals has been developed as a result of observing that pressure-treated creosoted wood is more resistant to the attack of acids than untreated wood. It has further been observed that, if the wood is pres-

sure impregnated with 50/50 solutions of creosote-coal tar, the resistance to chemical attack is further improved. As a result of these observations, Koppers Company has developed a special acid-resistant bituminous thermoplastic compound, with a melting point of about 140° F. Wood pressure impregnated with this compound is called *Asidbar*.

Dry wood to be acid-proofed is loaded on small trams and placed into large cylinders or retorts capable of withstanding pressures up to 200 lbs. per square inch. A vacuum is pulled

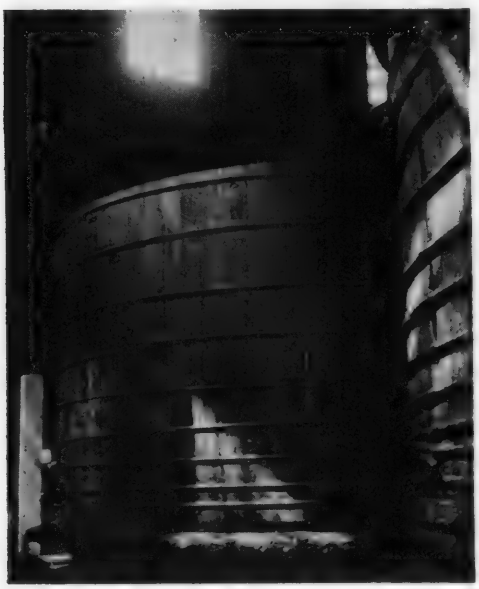

Fig. 1.—Tank made of Asidbar. Lumber used for storing aluminum chloride solution.

upon the cylinder to exhaust the air from the cells of the wood. Still maintaining the vacuum, the molten plastic is run into the cylinder until the cylinder is filled; a static pressure is then built up on the plastic in the cylinder and held for 24 to 36 hours, during which time both the cavities and cell walls of the wood are filled.

Following the pressure impregnation, the wood can be processed so that it either has a smooth shiny coat over the entire surface of the wood or the coating can be removed so that the wood is black but has no excess compound on the surface. The amount of plastic impregnated into the wood increases the weight of the wood by about 50 percent. Due to the high viscosity of the impregnating compound, only easily treatable wood such as southern yellow pine and black gum can be acid-proofed.

Acid Resistance

The acid resistance of Asidbar is illustrated by laboratory tests reported as follows:

Relative Hardness of Asidbar, Untreated and Creosoted Wood After Submersion in Acid Solutions

Species—Southern Yellow Pine.

Percentages shown are based on water-wet untreated wood hardness at 100%.

A. Continuous submersion in Acid 56 days at 60–75° F.

	Water Wet	2½% HCl*	15% HCl	2½% H_2SO_4**	15% H_2SO_4
Asidbar	110%	129%	104%	110%	107%
Untreated wood	100%	73%	39%	94%	73%
Creosoted wood	100%	95%	52%	98%	86%

B. Intermittent submersion; 8 hours in acid, 16 hours in air for 56 days:

Asidbar	110%	135%	129%	152%	143%
Untreated wood	100%	70%	35%	85%	61%
Creosoted wood	100%	105%	72%	112%	113%

* HCl—hydrochloric acid.
** H_2So_4—sulphuric acid.

Characteristics of Bituminous Impregnated Wood

Wood impregnated with sufficient thermoplastic bituminous resin to increase its weight approximately 50 percent has the following characteristics:

It is resistant to dilute acid solutions and vapors.

It has a substantially lower rate of pick up and loss of moisture than does untreated wood.

It has increased dimensional stability due to this slower rate of moisture change. Therefore, tanks made with this material will not dry out as quickly during periods of idleness.

It has high weathering resistance, hence, does not need to be painted.

It has high resistance to attack by insects and decay.

It has increased resistance to abrasion and wear.

It can be worked with ordinary wood-working tools.

Fig. 2.—Duck boards after 18-months service subject to dripping acid. White oak under same conditions has an average life of less than 3-months.

The surface is dry and non-tacky up to 140° F.

The material is black in color and somewhat harder and heavier than untreated wood.

Applications of Bituminous Impregnated Wood

Wood treated with this bituminous compound has been successfully used in the following types of application:

For filter plates and frames, used for filtering acid solutions.

Tanks for storage of acids and acid salt solution (Fig 1).

Duck boards, walks, platforms, subject to acid spillage or trucking of acid dripping loads.

Stacks and ducts to exhaust acid vapors.

Drainage boxes for draining of acid waste solutions.

Structural lumber and timber used in plants subject to corrosive vapors.

Heavy duty platforms to resist abrasion, wear, weathering, and rot.

To determine whether wood, specially processed to resist chemical attack, is suitable for any given application, it is necessary to try samples of the wood under identical conditions. There are so many variables and requirements of processes that, in most cases, it is preferable to run preliminary tests before making full installations. In most cases, relatively short periods of time will tell if acid-proofed wood can satisfactorily be used. For instance, duck boards in one plant subject to acid spillage when made of untreated white oak lasted only 3-months; Asidbar used in this same application was perfectly sound after 18-months (Fig. 2).

Discussion

Mr. V. C. Otley (The Barrett Division, Allied Chemical and Dye Corporation): The subject matter of this paper should be of particular interest to those engaged in plant operations involving the production or handling of acids and corrosive chemicals. The life of wood subjected to chemical attack has long been a problem in such plants and today, with substantially higher material and labor costs, prolongation of the life of wood installations has become increasingly desirable.

In the field of resin protection, some promise of worthwhile results has been obtained with paint-coat application of varnish prepared from paracoumarone-indene resin, phenolic resin, and China wood oil. This material should prove even more effective under pressure-impregnation, as described for phenol-formaldehyde resin.

Bituminous impregnation, utilizing high melting-point material, offers a cost advantage over the resin methods, while retaining a high degree of protection. The "Asidbar" treatment referred to in the subject report appears to be a refinement of the so-called "Niggerizing" treatment which was in some use during the early part of the recent war. The latter process utilized pressure treatment and a medium-heavy refined coal tar to protect lumber and piling at coastal chemical plants against chemical attack and marine organisms.

The resin and bituminous methods described would seem particularly warranted, despite the relatively higher cost of treatment, for many special-purpose applications.

Mr. Charles B. Hemming (United States Plywood Corporation): Mr. Bescher mentions some of the treatments which have been used to afford protection to wood against the corrosive action of chemicals, particularly acids. We have tested many of these treatments ourselves, in order to develop sound recommendations for our customers. As a result, we have come to two conclusions, namely, that the protective agent must cover the wood in a continuous film even when impregnation is used, and that everything considered, pitch of the proper type is about as good as protective agent as there is available.

Our first conclusion is the result of noting that, if there is no surface film protection, the acid will erode the surface layer of fibers and slowly but definitely proceed inward no matter how efficient the treating agent. I would like to ask Mr. Bescher if he has noted this effect and what his conclusions are.

Mr. Bescher: I do not know that we have noted exactly the effect you describe, but it seems logical. In any event there appears to be no question about the suitability of pitches of the proper type in such services.

Vapor Drying: The Artificial Seasoning of Wood in Vapor of Organic Chemicals

Monie S. Hudson
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The first successful commercial application of the principle of utilizing vaporized media other than steam or fixed gases to the drying of wood was effected in 1945 at the Spartanburg, S. C., Plant of the Taylor–Colquitt Wood Preserving Company. The process employed in this operation had, at that time, a background of over five years development in laboratory and semi-commercial pilot plant stages.

DURING the period 1865 to 1875 several attempts were made to apply this principle to the drying of wood, but the processes developed failed to achieve commercial success because of improper processing techniques resulting from inadequate understanding of the problem. Most of these failures can be attributed to the fact that actual distillation of the drying agents used could not have occurred under the conditions employed in carrying out the processes (4, 13, 14, 15). Other investigators attempted to obtain higher concentrations of the organic agents in contact with the wood, by bubbling superheated steam or hot air through such substances as coal tar to obtain partial pressure distillation (2, 3), but such practices resulted in considerable degrade to the wood being processed as a result of hydrolysis by the steam and charring by the heated air.

Prior to the development of the present process, more recent work involving the use of organic vapors for treating wood was that of Besemfelder (1) in Germany in 1910, and Williamson (16) in this country in 1937. The latter process was developed mainly for the purpose of pitch elimination, rather than for drying. The Besemfelder process in general employed very low-boiling drying agents, such as ether and carbon disulphide, and as far as is known was never used commercially.

The Vapor Drying Process being used by the Taylor–Colquitt Company employs any of a large number of organic drying agents, such as those listed in U. S. Patent 2,273,039 (5). In the usual method of operation, drying agents that are immiscible with water are employed, since the separation of water and drying agent can be brought about by simple gravity separation. In Figure 1 is shown an all-glass laboratory vapor-drying unit designed for operation with organic substances that are immiscible with, and lighter than, water. The three-necked distilling flask A., containing the drying agent to be vaporized, is connected to the drying chamber B. through vapor line C. Vapor discharging from the cylinder passes through line D. to the condenser E. Mixed condensate containing water and drying agent separate by gravity in the separator F., the water settling to the bottom and the drying agent overflowing to pass through line G. and return to the evaporator. In operating the process, the drying agent in the flask is first brought to the boiling point and, after the wood has been placed in the drying chamber or cylinder, the vapor inlet valve H. is opened and also valve I. to vent the system to the atmosphere. The entering vapor immediately condenses on contacting the cool wood and walls of the cylinder, and the resultant condensate returns to the flask through line J., which joins return line G. when valve K. is opened. After a few minutes the walls of the cylinder and surface of the wood are heated sufficiently so that condensation in the cylinder has decreased, and vapor then begins to be displaced from the cylinder to the condenser through line D. The air in the cylinder is displaced and escapes through line L. to the atmosphere. By the time that the vapor begins to pass over to the condenser, it will contain a

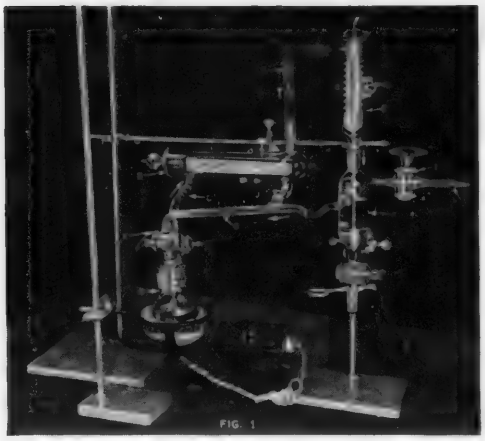


Fig. 1.

substantial amount of water vaporized from the wood as it is heated by the condensing drying agent vapor. In fact, the first condensate will be composed of approximately 50 percent water and 50 percent organic drying agent. As heating is continued, the percentage of water in the vapor decreases sharply, although the actual amount delivered to the condenser remains about the same. This is occasioned by the fact that, as the cylinder walls and contents heat up, less of the organic drying agent condenses in the cylinder and, since the heat input remains about the same, more of the drying agent will pass over to the condenser. The percentage of organic agent in the vapor entering the condenser is allowed to increase to a point between 65 and 90 percent and is thereafter maintained in that range by control of the heat input to the evaporator. This control is governed by temperature of the effluent vapor, as the partial pressure of the drying agent establishes the percentage composition of the effluent vapor, since the water vapor component behaves as a fixed gas. At organic agent concentrations below about 65 percent it has been found that the drying rates decrease very rapidly, while above 90 percent the drying rates increase but little, although the heat input required to maintain the higher concentrations increases very rapidly. At the condenser, the vapor mixture of steam and drying agent is cooled to about 180° F. and the resulting condensate passes downward into the separator where gravity separation occurs. The water-free drying agent returns to the flask to be revaporized, while the water settles out and may be withdrawn as desired.

At the time that the stable operating conditions are established, that is, when the effluent vapor temperature indicates that the composition with respect to organic agent in the vapor discharging from the cylinder is at the desired level, the water removal will have reached a maximum. In small equipment, such as the glass unit shown, the time required is about 10 minutes. In the commercial unit this time is about 30 minutes. From this point on, the amount of water removed decreases as drying progresses. In the case of wood of small dimensions that requires only a short time to dry, the decrease in the amount of water removed is rapid, while with pieces of large dimension that require longer drying periods the amount of water removed per hour decreases more slowly. Since the effluent vapor is maintained at a uniform composition throughout the run, the heat input to the evaporator is decreasing uniformly as the amount of water removed decreases.

During this period of heating in vapor, much of the drying agent that condenses on the wood, to supply heat to vaporize the water, is absorbed by the wood. The amount absorbed, however, is not as great as the amount of water being lost. In easily penetrable woods, such as southern pine, about one pound of drying agent is absorbed for each two pounds of water lost. With difficulty penetrable woods, such as white oak, this ratio is more nearly one to four. When the moisture content of the wood has been reduced to the desired level, which is determined by weighing or measuring the water received at the separator, the evaporator is cut off from the cylinder and a vacuum is impressed on the cylinder to recover the drying agent that is condensed in the wood. Duration of this vacuum ranges from 30 minutes to 2 hours, depending on the size of the timber. The depth of this vacuum reaches 22 to 26 inches of mercury. In the case of timber being dried preparatory to preservative impregnation, the final moisture content usually ranges from 25 to 40 percent. During the vacuum, some water is removed from the timber, along with

the drying agent. The amount is usually 10 to 20 percent of the total removed from the charge during the cycle of heating in vapor. The amount of drying agent retained by the wood at the end of this vacuum ranges from 0.25 to 0.50 pounds per cubic foot, in wood dried for purposes of preservation. Readily penetrable species show retentions up to about 0.75 pounds per cubic foot, while impervious species retain only traces. In relatively thin material, such as one or two-inch boards, dried to low moisture content for general lumber use, the retention of drying agent after the vacuum is very low, varying from only traces to about 0.5 percent of the oven-dry weight of the wood. In order to obtain this virtually complete recovery of drying agent, it is necessary to reduce the moisture content to about 4 percent before the vacuum is applied, so that the sensible heat contained in the wood is not dissipated by the large heat of vaporization of water before all of the drying agent has been vaporized. However, since the drying rate is extremely rapid in thin material, the necessity for reducing the moisture content to this low value adds but little to the time required for the drying operation. The total time required for drying one-inch-thick green southern pine from an initial moisture content of 100 percent is about 7 hours.

Ideal drying agents for use in this process would, of course, be pure compounds, since the boiling point of a given drying agent would be invariable. But since the cost of pure compounds would be prohibitively high for an operation of this type, it is necessary in selecting suitable drying agents to compromise between the ideal of physical properties and cost. The general specification for purchase of drying agents that has been developed through balancing these considerations is as follows:

1. The drying agent shall have an initial boiling point between 212° F. and 400° F.
2. Not less than 75 percent shall distill in the first 25° F. after the first drop.
3. The material shall liberate no corrosive products when refluxed for prolonged periods in the presence of water vapor.

Although the above limitation on boiling range is rather broad, it has been found that materials meeting this requirement show but little increase in boiling point from charge to charge, since the vapor-drying equipment shows much less tendency to fractionate the drying agent than does Engler or similar distilling apparatus. In the vapor-drying equipment the temperature obtained is more nearly that of the average boiling point of the drying agent, as determined in laboratory distilling apparatus. The chief factors influencing rise in the boiling point of the drying agent in use are: (1) Transfer of resinous material from the wood to the drying agent by the extracting action of the drying agent condensing on the wood. This effect has been found to be very slight except in the case of highly resinous wood in the form of chips or shavings. Extraction of resins from massive pieces, such as poles or ties, is negligible, being confined to the outer $\frac{1}{16}$ or $\frac{1}{8}$ inch; (2) transfer of preservative treating agents, such as creosote, to the drying agent in the evaporator by extraction from the cylinder walls, pipelines, etc. Although these sources of contamination raise the apparent boiling point of the drying agent in the evaporator, the rise has not been found to be reflected in the drying-chamber temperature. Apparently the effect is merely to superheat the drying agent as it leaves the evaporator, and this effect is lost immediately in the cylinder where active condensation is occurring in giving up heat to the charge, so that saturation conditions are maintained. This makes it possible to run a large number of charges without experiencing increasing temperatures in the drying chamber over the series. Continuous return of drying agent from the separator to the evaporator also acts to maintain uniformity of temperature through a large number of runs. When the accumulation of these extraneous substances in the drying agent has reached the stage where the boiling point rise begins to affect the rate of heat transfer from the source of heat to the boiling drying agent, by decreasing the temperature difference, the drying agent is removed from these residues by distillation, usually employing vacuum toward the end. The residues are then removed from the evaporator (to preservative storage in case the residue is creosote that has been extracted from the cylinder) and the evaporator is refilled with

the distilled drying agent and a new series of runs is started.

In selecting drying agents for use in the process, a number of others factors are considered that are not listed in the above specification outline. The first of these is the working temperature available in the plant for boiling the drying agent and, since in most cases the source of this heat will be saturated steam, the criterion for this factor is boiler pressure. The temperature difference required between that of the source of heat and that of the boiling liquid for satisfactory operation varies from about 30° F. to 70° F., depending on the size and design of the heat exchanger employed. To date the heat exchangers used in this process are of the free convection type, consisting of coils situated in horizontal or vertical evaporators.

Since the rate of drying increases rapidly with increase in temperature up to about 325° F. (6), the drying agent selected for use in a given installation would be one having a boiling point as near this value as the available steam temperature would permit, other considerations being equal. For example, in a plant where a working pressure of 150 p.s.i. gauge is available, the steam temperature would be 365° F. and with a heat exchanger designed to operate at a temperature head of 40° F., a drying agent boiling at 325° F. could be used.

In Table 1 are shown some of the commercially available coal-tar and petroleum fractions that have been found to be suitable as vapor-drying agents. These have been roughly divided into groups corresponding to three ranges of boiler pressure. This classification is based on the maximum boiling point that could be handled with a given boiler pressure. Any of the agents shown in the table could, of course, be used with the 125–150 p.s.i. pressure range. Also it would be possible to use any of the drying agents in Group 1 at boiler pressures in the range shown for Group 3, by lowering their boiling points by application of vacuum. However, in order to obtain satisfactory recovery of drying agent during the vacuum after heating in vapor, it has been found that a differential vacuum of 12 to 15 inches should be available, that is, the operation of heating in vapor should not be carried out under a vacuum greater than 10 to 13 inches of mercury, if the vacuum available for the recovery step is 25 inches of mercury. Operation of the process under pressure, to raise the boiling point of low-boiling agents is possible, but is not recommended because of the hazards introduced by the possibility of leaks from the system.

Another important factor that must be considered in selection of the drying agent, when vapor drying is to be used in conjunction with preservative agents such as creosote or creosote coal-tar solutions, is chemical characteristics. In such cases the drying agent should have sufficient compatibility with the preservative to prevent the formation of insoluble resinous products that would be deposited on the evaporator heating surfaces and cut down the rate of heat transfer. A fairly reliable means for determining this is by refluxing the drying agent for about 48 hours, in the presence of the preservative in a flask containing clean iron rods, and then examining the rods for resinous

TABLE 1.—LIST OF SOME COMMERCIALLY AVAILABLE VAPOR DRYING AGENTS FOUND SUITABLE FOR USE IN EQUIPMENT UTILIZING VARIOUS STEAM PRESSURES

1. Steam Pressure 125 to 150 p.s.i. gauge (353° F to 365° F)			
Drying Agent	K-4	S-80	G.S.-320
Source	Coal Tar	Petroleum	Petroleum
Specific Gravity 100/100° F	0.952	0.767	0.777
Distillation Range*	300° F to 395° F	295° F to 360° F	320° F to 375° F
2. Steam Pressure 100 to 125 p.s.i. gauge (338° F to 353° F)			
Drying Agent	S-280 (Xylol)	S.N.-B	S.N.-C
Source	Coal Tar	Petroleum	Petroleum
Specific Gravity 100/100° F	0.860	0.831	0.812
Distillation Range*	275° F to 300° F	285° F to 338° F	260° F to 338° F
3. Steam Pressure 75 to 100 p.s.i. gauge (320° F to 338° F)			
Drying Agent	Toluol	V-250	A.S.-3443
Source	Coal Tar	Petroleum	Petroleum
Specific Gravity 100/100° F	0.854	0.742	0.766
Distillation Range*	230° F to 270° F	230° F to 285° F	250° F to 300° F

*AWPA Standard Method of Distillation, 11 g.

deposits. The usual tests for aromaticity, such as the kauri-butanol, dimethyl sulphate, or aniline point, may also be used as guides for selecting agents which will be compatible with coal-tar products. Coal-tar distillates like toluol, xylol, and naphthas will be found to give no trouble from this standpoint. As a rule almost any vapor-drying agent can be used to prepare wood for impregnation with toxics such as pentachlorophenol or copper naphthenate in petroleum solutions, or inorganic salts in aqueous solution. However, in the case of the latter, it should be pointed out that drying agents containing easily oxidizable components should not be used in the presence of active oxidizing agents, such as dichromates or chromic acid. The small quantities of drying agent retained by the timber have shown no tendency to interfere with the penetration of water-borne preservatives, even though the drying agent itself is immiscible with water.

A number of tests that have been conducted to determine the effect of chemical constitution of the drying agent on the rate of drying have shown no difference between drying rates obtained with aromatic or straight-chain compounds, when the boiling points are the same.

A final point that is of importance in selection of the drying agent is that of the solidification temperature of the chemical. Since a liquid phase separation of water and drying agent is performed, it is necessary that the mixture be cooled below the boiling point of water to effect complete condensation, because the mixture of the two immiscible substances will have a boiling point below that of the water. To prevent the escape of any of the drying agent from the system, which is open to the atmosphere, it has been found necessary to cool the mixture to at least 180° F. at the condenser. If the drying agent solidifies or begins to deposit solid constituents at temperatures above 180° F., the condenser tubes will be coated and proper performance prevented. For this reason the drying agent should contain no crystalline material when heated to 180° F.

The drying agents so far mentioned have been substances immiscible with water which can be used in equipment of the type shown in Figures 1 and 2. With drying agents such as alcohols, ethers, ketones and esters, it is necessary to replace the gravity separator with a

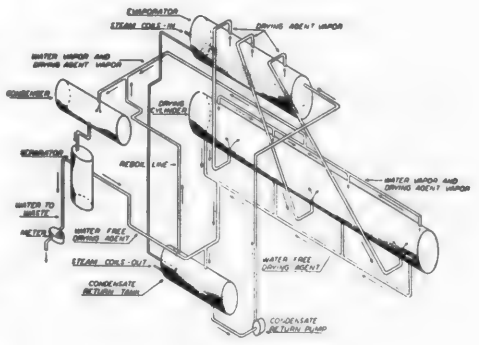


Fig. 2.

fractionating column for separation of the drying agent and water. Because of the added operating difficulty, introduced by the necessity of using the fractionating equipment, the water-soluble drying agents are only used in special cases where the character of the wood being dried is such that injury from excessive shrinkage would occur with non-polar agents, or where it is desired to impregnate the wood with polar agents during drying in order to form resins, etc. in the wood by subsequent treatment with other chemicals that react with them.

Equipment for large-scale operation of the vapor-drying process consists of an evaporator, drying chamber, condenser, separator, and condensate return tank as shown in Figure 2. All of these units are designed to withstand 24 to 28 inches of vacuum. Units that are used for impregnation with preservatives after vapor drying will, of course, require drying chambers or cylinders capable of withstanding the working pressure to be used. The materials of construction may be of mild steel, except for the condenser tubes and aqueous condensate drains, which should be fabricated of Admiralty or other mildly acid corrosion resistant metal. The aqueous condensate has been found to contain traces of lower fatty acids which makes this necessary. No other material than these fatty acids has been found in the aqueous condensate. The other elements of equipment are operated under virtually anhydrous conditions so that corrosion in them is negligible.

The condensate return tank, which is an item not shown in Figure 1, serves to pool the organic drying agent from the cylinder and the

condenser and to allow it to be preheated with waste heat from the evaporator coils before it returns to the evaporator. The preheating also eliminates any traces of water from this condensate, by allowing it to boil off and return through the reboil line to the condenser, thus assuring return of water-free drying agent to the evaporator. This tank also acts as a trap for wood chips, shavings, and other debris received through the cylinder condensate drain lines.

The separator shown in Figure 2 is a simple vertical tank of small size divided by a vertically arranged baffle running from a point near the top to within a short distance of the bottom. The outlets for water and drying agent are placed at different elevations, depending on the relative densities, so that the interface of separation is balanced at a point about midway from top to bottom of the tank, and the separation takes place continuously, requiring no manipulation.

Heat input to the system during the start-up period is controlled by a thermal element situated in the line draining the condenser which regulates the heat input so that the temperature of the condensate cannot exceed 180° F. When stable operating conditions have been reached, control of heat input is transferred to another thermal element in the cylinder effluent vapor line to maintain the desired ratio of water to organic agent delivered to the condenser throughout the run.

Although the rapidity of drying by means of the vapor process is accomplished by exposure of the wood to vapors condensing at relatively high temperatures, the results obtained from the standpoint of incidence of checking and splitting and other factors tending to degrade the finished product are as a rule much better than those obtained by conventional seasoning or conditioning practices. At the outset, it was believed that reduction in the incidence of checking and splitting could be attributed to some specific action of the drying agent in replacing the water so as to prevent the unbalanced shrinkages that produce these injurious results. However, it has been found that the amount of shrinkage obtained in most species is normal, and this has led to the conclusion that, although drying stresses comparable to those produced by other methods are developed in the wood, the duration of stress applied to given laminae is so short, because of the rapid drying, that the strength-time limit of resistance of the wood to failure is not exceeded. Other deterrents to the use of high temperatures in the drying of wood are oxidation, hydrolysis, and thermal decomposition. The first of these is excluded in vapor drying since the wood is blanketed in an atmosphere of a chemical that is inert with respect to reaction with the wood. Effects of hydrolysis are limited, as will be shown later, by the fact that the wood itself remains at a temperature in the neighborhood of the boiling point of water as long as much water is present. This likewise eliminates the occurrence of any appreciable amount of thermal decomposition, which requires much higher temperatures to produce significant effects in short periods of time. In the temperature range prevailing in the wood during vapor drying both of these latter phenomena proceed at relatively slow rates and, since the vapor drying is completed in a comparatively short time, their effects are negligible.

The semi-commercial pilot plant used in the development of the vapor-drying process consists of a conventional pressure impregnation unit which was adapted for vapor drying by installing the four units required for such a conversion, viz., an evaporator, condenser, separator, and condensate return tank. The treating retort to which these elements were added has a diameter of three feet and a length of 26 feet. This vessel, which is used as the drying chamber, also serves its former purpose as a treating retort for impregnation of the charges after vapor drying.

In carrying out vapor drying tests, the poles or other timbers in each charge are weighed individually and measured to obtain length and other dimensions. With round timbers, diameters are taken at butt, midpoint and top. A check on the total charge weight is obtained by means of the cylinder scales when the charge is placed in it. After introduction of vapor to the cylinder is begun, readings are taken at half hourly intervals to determine water removal, vapor temperatures, and internal temperatures of the wood. The water removal is determined directly by separating from the drying agent all water received from the condenser in a half hourly interval. The separator used in this instance is a cone shaped tank,

similar to a separatory funnel with sight glasses at the bottom of the cone for making the batch separations. During the vacuum, after completion of the cycle of heating in vapor, these readings are continued. At the end of the vacuum the charge is removed from the cylinder for weighing and measuring, unless the drying is to be followed immediately by impregnation.

The amount of drying agent used in processing the charge is determined in three ways: (1) By deducting the total water recovered at the separator from the initial green weight, to obtain the drywood weight with no drying agent retained. Subtraction of this value from the final weight of the charge after drying gives the amount of drying agent retained. (2) By extraction of samples taken from the wood after vapor drying. (3) By inventory of the drying agent in the evaporator before and after drying. The first two of these methods have been found to be more accurate, since inventorying of the drying agent is complicated by the fact that creosote or other impregnating agents enter the evaporator by extraction from the cylinder, thus requiring that corrections in the evaporator readings be made, based on analyses of the drying agent before and after drying.

In Table 2 are shown the operating conditions used and the results obtained in vapor drying 35 charges of southern pine poles in the semi-commercial pilot plant, using the drying agent designated as K-4 in Table 1. The data in Table 2 are arranged in groups of increasing diameter. It will be noted that as many as ten poles could be handled in one charge in the smallest diameter group, while only one or two of the largest diameter group could be placed in the cylinder at one time. All of the poles listed in this table were 25 feet in length and with the exception of those in Groups 1, 7 and 8, and charges 204 and 205 in Group 4, and 208 and 209 in Group 6, were taken from normal incoming pole shipments to the commercial plant. Poles for the groups or charges just specified above were brought to the pilot plant by special handling, in order to keep them as nearly as possible at the moisture content present when they were cut. All of these were moved to the plant with the bark left on, and were used in vapor-drying tests as soon as possible after they were received. These poles were trammed for the vapor-drying tests immediately after machine peeling.

The average diameters shown in Table 2 for the charges were obtained from measurements at butt, midpoint and top of each pole in the charge. The green weights per cubic foot were obtained by weighing the individual poles and using the volumes calculated from the above measurements. In some cases the charges were removed from the cylinder after vapor drying. Weights and measurements taken in these cases were used in calculating the average vapor-dried weights per cubic foot shown in Column 5. The oven-dry weight at green volume values reported in Column 6 represent the average found by density determinations on discs cut from the butts and tops of each pole in the charge. The volumetric shrinkage values shown in Column 7 represent the average shrinkage from green to vapor dried for the charges that were vapor dried only. Shrinkage reported for the remainder of the charges represents that found from green to vapor dried and impregnated. Since it has been found that no change in volume from vapor dried to impregnated occurs when creosote or similar preservative agents are used, these latter values may be considered as shrinkage produced in vapor drying. The absence of any volume change effect from impregnation with these substances results from the fact that they are as a rule non-polar and hence unable to produce swelling of the wood.

The operating temperatures shown in Column 9 of the table are averages of the half-hourly readings taken of temperatures of the vapor discharging from the cylinder during the run. The temperatures existing during the first hour are not included in this average since this is a start-up period during which the drying chamber is being brought up to operating temperature. It will be noted that the average temperatures show an increase from charges of the lower diameter groups to those of the larger diameter groups. This results from the fact that the charges require somewhat more than an hour to reach the operating level and the effect of this is greater in the average for the short time periods used in drying the smaller poles. As was pointed out previously the composition of the effluent vapor with

TABLE 2.—VAPOR DRYING TESTS ON SOUTHERN PINE POLES

Charge No.	No. of Poles in Charge	Average Diameter Inches (3 Points)	Weight per cu. ft. at Volume Shown: Green	Vapor Dried	Oven Dry At Green Volume	Volumetric Shrinkage Green to Vapor Dried or Treated % of Green Vol.	Hours Heating in Vapor	Drying Conditions: Avg. Efficient Vapor Temp. After 1st Hour °F	Hours Vacuum After Heating in Vapor	Vacuum, Inches of Mercury	Water Removed in Drying Lbs./Cu. Ft./Green Vol.: Heating in Vapor	Vacuum After Heating in Vapor	Total	Moisture Content % of Oven Dry Weight: Initial	After Heating in Vapor	After Hot Vacuum	Retention of Drying Agent Lbs./Cu. Ft.: By Method 1. Described in Text	By Inventory of Evap. (Method 3 Described in Text) Evap.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)
					GROUP 1													
152	10	5.96	59.07	45.37	30.88	3.7	6	292	2	26.3	13.49	2.22	15.71	91.2	47.4	40.5	0.38	1.74
					GROUP 2													
238	8	7.21	46.92	------	------	3.6	10	303	1	25.0	12.75	1.13	13.88	51.7	10.5	6.9	------	1.88
226	9	7.55	46.05	------	------	2.9	6	296	1	24.3	6.41	1.10	7.51	48.9	28.2	24.6	------	Negative
183	6	7.59	52.52	------	------	1.7	6	306	2	26.1	8.08	1.94	10.02	73.4	46.7	40.3	------	0.61
224	9	7.61	51.57	------	------	3.4	10	299	1	25.0	13.04	1.08	14.12	66.7	24.5	21.0	------	Negative
229	8	7.65	47.76	------	------	3.3	8	300	1	25.5	9.96	1.10	11.06	54.4	22.2	18.7	------	1.26
Average		7.52						301						59.0				
					GROUP 3													
239	7	7.79	48.66	------	------	4.3	10	302	2	25.8	12.09	1.71	13.80	57.3	18.2	12.7	------	Negative
235	6	7.86	48.56	------	------	4.1	10	312	1	25.7	11.05	1.34	12.39	57.0	21.2	16.9	------	1.73
234	6	8.08	50.84	------	------	3.9	10	310	1	25.8	13.75	1.37	15.12	64.4	19.9	15.5	------	Negative
232	6	8.22	51.24	------	------	3.7	10	308	1	25.0	13.89	1.08	14.97	65.7	20.8	17.3	------	1.88
231	6	8.24	53.17	------	------	3.4	10	309	1	24.7	14.23	1.04	15.27	71.9	25.8	22.5	------	1.09
Average		8.04					10	308						63.3	21.2	17.0	------	--------
					GROUP 4													
233	6	8.26	49.03	------	------	3.7	10	311	1	25.5	10.39	1.51	11.90	58.5	24.9	20.0	------	Negative
182	4	8.30	47.31	------	------	1.8	12	316	3.5	26.6	6.46	1.57	8.03	57.3	20.1	14.7	------	0.32
204	6	8.41	58.76	------	29.05	4.0	18	307	2	25.7	18.74	1.62	20.36	102.3	37.8	32.2	------	--------
218	5	8.54	49.91	------	------	1.8	10	312	1	25.3	10.58	1.26	11.84	61.4	27.2	23.1	------	2.14
205	6	8.74	60.70	------	32.39	3.9	18	314	2	26.0	18.66	1.66	20.32	87.4	29.8	24.6	------	2.47
Average		8.45						312						73.4				
					GROUP 5													
213	4	9.00	57.10	41.36	------	3.3	12	313	.5	26.3	16.38	0.97	17.35	84.6	31.7	28.5	0.27	--------
216	5	9.17	54.79	43.48	------	3.5	12	313	.5	26.1	13.11	0.79	13.90	77.1	34.8	32.2	1.11	1.10
221	5	9.20	54.23	------	------	4.2	15	316	1	25.9	12.78	0.68	13.46	75.3	34.0	31.8	------	0.48
217	4	9.26	53.37	39.91	------	3.3	10	311	1	25.4	13.60	0.97	14.57	72.6	28.6	25.4	Negative	0.04
Average		9.16						313						77.4				
					GROUP 6													
212	4	10.02	56.30	41.22	------	2.6	14	311	.5	25.7	15.52	0.81	16.33	82.0	31.8	29.2	0.63	2.52
209	2	10.55	59.45	------	31.62	3.2	18	312	.25	25.9	17.31	0.99	18.30	88.0	33.2	30.1	------	0.99
222	4	10.71	55.33	------	------	1.9	15	314	1	25.0	13.96	0.83	14.79	78.9	33.8	31.1	------	0.05
220	4	10.73	55.70	------	------	1.4	15	316	1	22.7	12.03	1.14	13.17	80.1	41.2	37.5	------	2.73
208	3	10.82	53.45	------	30.83	2.8	18	317	.25	25.6	15.56	0.59	16.15	73.4	22.9	21.0	------	1.92
Average		10.57						314										
					GROUP 7													
198	4	11.02	56.51	------	32.08	3.5	18	314	2	25.9	13.92	1.75	15.67	76.2	32.8	27.3	------	--------
166	3	11.08	57.36	------	27.80	2.5	14	314	2	25.8	14.16	1.33	15.49	106.3	55.4	50.6	------	2.30
199	3	11.30	57.94	------	31.27	2.9	18	322	2	26.4	15.09	1.72	16.81	85.3	37.0	31.5	------	--------
155	3	11.99	54.42	39.20	27.90	2.5	18	309	2	26.0	16.26	.94	17.20	95.1	36.8	33.5	1.03	2.04
Average		11.35						315						90.7				
					GROUP 8													
156	2	14.96	59.83	47.19	30.41	1.9	18	310	2	26.6	13.49	0.96	14.45	96.7	52.4	49.7	0.95	1.36
181	1	15.16	59.13	------	28.90	1.9	18	322	2	26.7	13.11	1.16	14.27	104.6	59.2	55.2	------	0.92
178	1	15.50	56.87	------	32.86	0.6	18	331	2	26.4	14.18	0.46	14.64	73.1	30.0	28.6	------	0.86
161	2	15.62	56.05	------	27.22	2.2	24	315	2	22.8	13.71	0.45	14.16	105.9	55.5	53.9	2.38	2.58
179	1	16.32	54.46	------	27.73	0.9	18	323	2	26.4	11.67	0.80	12.47	96.4	54.3	51.5	------	0.80
180	1	16.39	58.97	------	30.42	1.1	18	320	2	26.8	13.19	1.00	14.19	93.9	50.5	47.1	------	0.77
Average		15.66						320						95.1				

respect to drying agent and water is governed by the partial pressure of the drying agent at the existing temperature. The average temperatures shown from about 300° F. to 320° F. indicate percentages of K-4 in the vapor, from about 80 percent to 90 percent on a weight basis.

The water removal figures shown in Columns 12, 13 and 14 of the table were obtained by direct weighing of water received from the charge at the separator for the periods shown. It will be noted that the total water removed, Column 14, is greater than the value that will be obtained by subtracting the vapor dried weights, where shown, from the green weights. The cause of this apparent discrepancy is mainly shrinkage during drying. In order to make this comparison the vapor dried weights must first be divided by one plus the shrinkage. The remaining difference will then be found to be retention of drying agent shown in Column 18.

The initial moisture content values of Column 15 were calculated for the charges on which oven dry weights at green volume were available, as follows:

(1)

$$\left(\frac{\text{Green Weight per Cu. Ft.}}{\text{Oven Dry Weight per Cu. Ft.}} \times 100\right) - 100$$

Initial moisture content of the other charges was calculated using an average value of 30.93 pounds per cubic foot for the oven dry weight at green volume in the above equation. This density value represents the average found by density determinations of butt and top discs from 114 poles run in charges 152 through 209. Table 2 does not contain data on density of all of these since many of them were run with different temperatures and drying cycles than those reported in this table. The moisture content values after heating in vapor, shown in Column 16, were calculated as follows, using the average density of 30.93 pounds per cubic foot where actual densities were not available:

(2)

$$\left(\frac{\text{(Green Weight per Cu. Ft.)} - \text{(Water Removed Heating in Vapor Lbs./Cu. Ft.)}}{\text{Oven Dry Weight per Cu. Ft. at Green Volume}} \times 100\right) - 100$$

The values for moisture content after the vacuum following heating in vapor were calculated as above except that the total water removed was subtracted from the green weight per cubic foot in the numerator.

Retentions of drying agent reported in Columns 18 and 19 of Table 2 were obtained by methods 1 and 3 described in a previous paragraph. Inspection of these columns reveals the rather erratic results found by inventory of the evaporator. Generally the amount used as determined by measurements and analyses of the drying agent in the evaporator are higher than those found by method 1, or by the extraction method 2, indicating losses other than by retention in the wood. This, however, has not been found to be the case in the commercial operation. The amount of drying agent used in this plant as found by inventory of the evaporator for the first one hundred and seventy-five charges processed there, representing about 500,000 cubic feet of timber, was found to be 0.51 pounds per cubic foot. Factors that would tend to show a greater amount used in the case of the pilot plant are (1) The batch method of separating water and drying agent at half hourly intervals when small losses occur; and (2) the fact that any losses would have a larger percentage effect on the relatively small volume of drying agent in the pilot plant evaporator than on the large volume of the commercial plant evaporator.

In Table 3 are shown the average moisture content values at hourly intervals for the groups of charges listed in Table 1. Data for Group 1 are not included since it contained only one charge run at relatively low temperature. These figures were obtained by progressively deducting the average moisture removals for given time periods found for the group, from the average initial moisture content of the group, to obtain the moisture content at the successive hours of heating in vapor. In Figure 3 these data have been plotted with the logarithm of moisture content as ordinates and drying time as abscissae. From this figure it will be seen that those values are related linearly over most of the drying period, which indicates that the progress of drying follows the mass action law. The intercept corrections in the constant term of the equations show a decrease from a positive value of 8 percent to be added

TABLE 3.—PROGRESSIVE REDUCTION IN MOISTURE CONTENT OF SOUTHERN PINE POLES DURING HEATING IN VAPOR

Group No. from Table 2	2	3	4	5	6	7	8
Avg. Diameter, Inches	7.52	8.04	8.45	9.16	10.57	11.35	15.66
Drying Time Hours	Moisture Content, % of Oven Dry Weight						
0	59.0	65.3	73.4	77.4	80.5	87.5	95.1
1	58.4	62.4	72.1	76.6	79.8	86.4	94.5
2	53.4	56.1	66.2	70.0	74.5	80.5	86.5
3	47.4	49.8	60.4	64.0	68.6	75.7	81.2
4	41.6	43.6	56.0	58.9	64.4	71.0	76.9
5	37.3	38.6	51.6	55.0	60.3	67.2	73.9
6	32.9	34.7	47.9	50.5	56.8	63.8	71.6
7	-----	30.9	44.6	46.5	53.6	60.8	68.7
8	-----	27.5	41.5	43.2	50.7	57.8	66.4
9	-----	24.4	38.8	39.8	47.8	55.2	64.5
10	-----	21.2	35.6	36.8	45.0	52.7	62.7
11	-----	-----	-----	-----	42.6	50.6	61.0
12	-----	-----	-----	-----	40.4	48.6	59.6
13	-----	-----	-----	-----	38.3	46.6	58.1
14	-----	-----	-----	-----	36.1	44.7	56.7
15	-----	-----	-----	-----	-----	-----	55.4
16	-----	-----	-----	-----	-----	-----	54.1
17	-----	-----	-----	-----	-----	-----	52.9
18	-----	-----	-----	-----	-----	-----	51.8

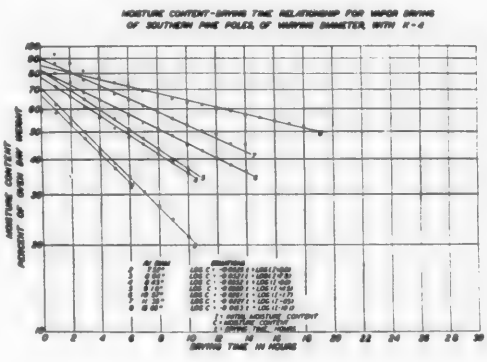

MOISTURE CONTENT - DRYING TIME RELATIONSHIP FOR VAPOR DRYING OF SOUTHERN PINE POLES OF VARYING DIAMETER, WITH K=4
MOISTURE CONTENT PERCENT OF OVEN DRY WEIGHT
DRYING TIME IN HOURS

Fig. 3.

to the initial moisture content of the Group 2 poles to a negative value of 10.1 percent to be subtracted from the initial moisture content of the Group 8 poles, to bring them into agreement with the equations. The plus intercept corrections are, of course, explained by the start-up lag in which about an hour elapses between the introduction of vapor to the drying chamber and the discharge of water from the separator. The decrease in intercept correction with increasing diameter of the poles is likewise explainable on the basis that the surface for condensation is greater in a charge of smaller poles which would lengthen the start-up lag, when the heat input at the start is the same as was the case in these tests. The fact that the intercept corrections pass to negative values in the case of the larger poles seems to indicate two periods such as the constant rate period and the falling rate period for drying reported by Rees and Buckman in their studies of moisture movement in wood above the fiber saturation point (12); the existence of the two differing rate periods being masked by the increasing effect of start-up lag in the case of the smaller poles. The possibility that the higher moisture content of the larger poles might be the factor causing this difference could be supported by the fact that in the constant rate period water is being lost at a rate almost equal to that from a free water surface, but as will be shown later the negative intercept corrections for the larger poles cannot be shown to be dependent on moisture content.

In Table 4 are shown the slopes and intercept correction values obtained by plotting, as in Figure 3, the data for each of the charges of Table 2. The major variables such as initial moisture content, diameter, drying temperature and density, where available, are shown for purposes of correlation. The order of arrangement within the groups in this table is one of descending magnitude of the slope constants. The italicized figures to the right of the slope column indicate the magnitude of the slope values for the whole series; the correlation numbers increasing with decreasing slope values. Comparison of these figures with those to the right of the diameter column which represent ascending order of diameter shows that in general the drying rates decrease with increasing diameter as would be expected. However, this correlation does not hold within the groups, and there is some overlapping from group to group. The correlation numbers opposite the initial moisture content values increase with increasing moisture content. The fact that

TABLE 4.—CORRELATION OF FACTORS AFFECTING RATE OF DRYING OF SOUTHERN PINE POLES BY THE VAPOR PROCESS

Charge No.	Slope of Equation Relating Leg of Moisture Content and Drying Time (1)		Intercept Correction. Difference Between Equation Intercept and Initial Moisture Content (2)		Average Diameter Inches (3 Points) (3)		Initial Moisture Content % (4)		Density Oven Dry Weight at Green Volume Lbs./Cu. Ft. (5)		Effluent Vapor Temperature Average After First Hour °F (6)	
					GROUP 2							
238	—0.0613	1	5.0	11	7.21	1	51.7	12	-----	--	303	5
229	—0.0591	2	9.0	4	7.65	5	54.4	3	-----	--	300	3
224	—0.0523	6	10.9	2	7.61	4	66.7	11	-----	--	299	2
226	—0.0501	7	7.2	7	7.55	2	48.9	1	-----	--	296	1
183	—0.0398	11	7.2	7	7.59	3	73.4	15	-----	--	306	6
Average	—0.0525	--	8.0	--	7.52	--	59.0	--	-----	--	301	--
					GROUP 3							
234	—0.0560	3	9.3	3	8.08	8	64.4	9	-----	--	310	12
232	—0.0557	4	11.1	1	8.22	9	65.7	10	-----	--	308	8
239	—0.0543	5	7.6	5	7.79	6	57.3	5	-----	--	302	4
231	—0.0485	8	6.0	10	8.24	10	71.9	12	-----	--	309	9
235	—0.0462	9	5.1	12	7.86	7	57.0	4	-----	--	312	17
Average	—0.0521	--	7.8	--	8.04	--	63.3	--	-----	--	308	--
					GROUP 4							
218	—0.0393	12	7.4	6	8.54	14	61.4	8	-----	--	312	17
233	—0.0391	13	2.0	20	8.26	11	58.5	7	-----	--	311	14
182	—0.0380	14	4.1	16	8.30	13	57.3	5	-----	--	316	26
205	—0.0333	16	3.1	17	8.74	13	87.4	25	32.39	2	314	22
204	—0.0265	21	1.3	21	8.41	15	102.3	31	29.05	1	307	7
Average	—0.0352	--	3.6	--	8.45	--	73.4	--	-----	--	312	--
					GROUP 5							
217	—0.0427	10	6.5	9	9.26	19	72.6	13	-----	--	311	14
213	—0.0377	15	4.2	14	9.00	16	84.6	23	-----	--	313	20
216	—0.0311	18	4.2	14	9.17	17	77.1	19	-----	--	313	20
221	—0.0285	20	3.1	17	9.20	18	75.3	17	-----	--	316	26
Average	—0.0350	--	4.5	--	9.16	--	77.4	--	-----	--	313	--
					GROUP 6							
212	—0.0314	17	5.0	13	10.02	20	82.0	22	-----	--	311	14
208	—0.0294	19	0.7	22	10.82	24	73.4	15	30.83	1	317	29
222	—0.0259	22	2.5	19	10.71	22	78.9	20	-----	--	314	22
209	—0.0242	24	0.1	24	10.55	21	88.0	26	31.62	2	312	17
220	—0.0194	28	0.1	24	10.73	23	80.1	21	-----	--	316	26
Average	—0.0261	--	1.7	--	10.57	--	80.5	--	-----	--	314	--
					GROUP 7							
155	—0.0252	23	— 0.5	27	11.99	28	95.1	28	27.90	2	309	9
198	—0.0227	25	0.4	23	11.02	25	76.2	18	32.08	4	314	22
166	—0.0215	26	— 0.3	26	11.08	26	106.3	34	27.80	1	309	9
199	—0.0213	27	— 0.8	28	11.30	27	85.3	24	31.27	3	322	31
Average	—0.0227	--	— 0.3	--	11.35	--	90.7	--	-----	--	315	--
					GROUP 8							
178	—0.0178	29	—10.8	32	15.50	31	73.1	14	32.86	6	331	34
156	—0.0137	30	— 4.8	29	14.96	29	96.7	30	30.41	4	310	12
180	—0.0123	31	—11.0	33	16.39	34	93.9	27	30.42	5	320	30
181	—0.0116	32	—10.3	31	15.16	30	104.6	32	28.90	3	327	33
161	—0.0109	33	— 9.6	30	15.62	32	105.9	33	27.22	1	315	25
179	—0.0102	34	—14.3	34	16.32	33	96.4	29	27.73	2	323	32
Average	—0.0153	--	—10.1	--	15.66	--	95.1	--	-----	--	320	--

these numbers show some agreement with those for slope, especially in the case of groups 6, 7, and 8, which would indicate the untenable conclusion that the drying rates decrease with increasing moisture content, is rather a result of the larger diameter poles having higher initial moisture content. Groups 7 and 8 had very high initial moisture content because all of these poles were brought to the plant with the bark left on to keep them as green as possible. In the other groups the higher moisture content of the larger poles is explained by the fact that they lose less water during the time that elapses between cutting and receiving at the plant, than do the smaller poles. The correlation numbers to the right of the equation intercept corrections are arranged according to decreasing magnitude. Possible reasons why these should show decrease with increasing diameter of the poles were presented in the discussion of Figure 3. That these corrections are not related to initial moisture content is indicated by the fact that those for the very green poles in the smaller diameter groups, charges 204, 205, 208, and 209, are of the same order as those of the low moisture content charges in their groups; and also by the fact that the relatively low moisture content charges, 178 and 198, in the high moisture content groups have intercept corrections that are in agreement with those of the high moisture content charges in these groups. Any effect of effluent vapor temperature on the drying rates is masked by the fact that these tend to increase as the diameters increase, but there is sufficient scattering to be found in the correlation numbers for temperature, which increase with increasing temperature, to indicate that the variation of temperature within this range exerts little affect on the drying rates. As was pointed out previously the drying rates tend to level off when the percentage of organic drying agent in the vapor is above 65 percent. The concentrations corresponding to the effluent temperatures in the series of runs range from about 80 percent to 90 percent and hence little difference in rate caused by temperature differences would be expected. Except in the case of Group 8 the correlation numbers opposite the density values which are arranged in descending order of density for the group, yield little indication of the decrease in drying rate with decrease in density that would be expected.

From the above analysis of the data it may be concluded that diameter is the major controlling factor influencing drying rate in this series of charges. Other factors that have not been considered such as percentage of sapwood and heartwood in the poles, wood structure, etc., probably influence the overall result. One indication of this is that the slope values tend to show greater variability in the smaller diameter groups, which represent as many as nine poles, than in the larger diameter groups that are made up of one to four poles.

In Figure 4 the slope values of Table 4 have been plotted against diameter, and the weighted curve drawn in to show the relation between diameter and drying rate. Figure 5 has been constructed using the slopes, read from this curve at various diameters, and intercept cor-

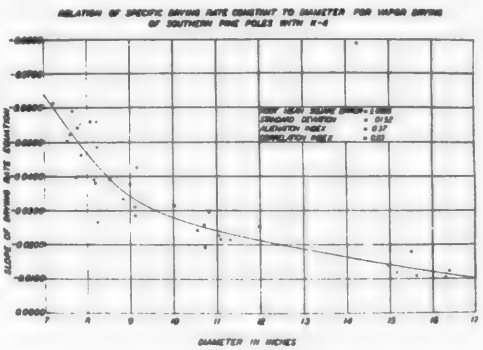


Fig. 4.

rections read from a similar plot of intercept correction against diameter. The latter plot was found to show a linear relation between intercept correction and diameter. The equations used in calculating the values for Figure 5 are shown on the graph. The upper set of plotted values were calculated on the basis of an initial moisture content of 100 percent, while those below represent the values for 70 percent initial moisture content.

From Figure 6 in which log of diameter has been plotted against time required to reduce the moisture content to 30 percent, from initial moisture content values of 50 to 100 percent; as calculated by means of the equations of Figure 5, it will be seen that the relationship derived breaks down mathematically for the

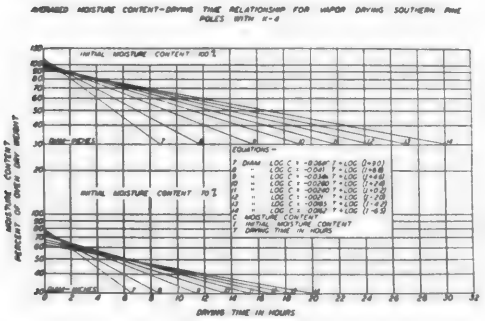


Fig. 5.

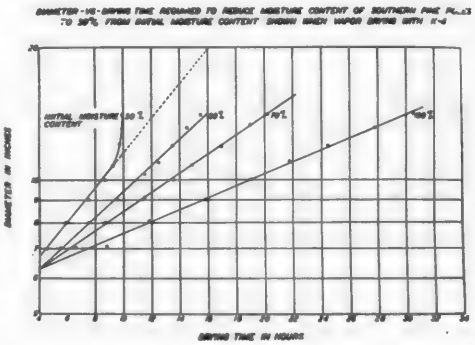
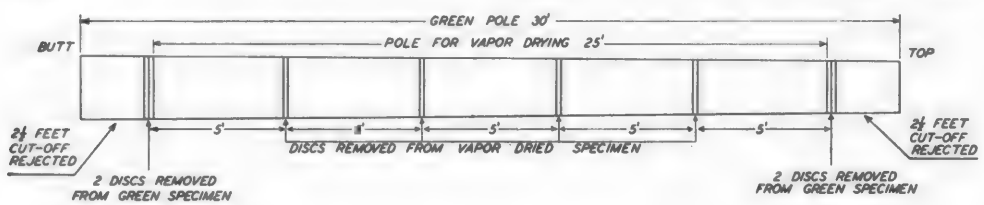


Fig. 6.

larger diameters between 50 and 60 percent. However, because of the consistency of the data for the smaller diameters it is probable that reasonably accurate values for the larger diameters at the lower initial moisture content values could be obtained by extrapolation from the data for smaller diameters as shown by the dotted line in the figure. Since the moisture content of most of the timber received in incoming shipments averages between 70 percent and 90 percent, these equations should be applicable to most of the vapor drying operations in which K-4 is used.

In Tables 5A, 5B and 5C are recorded initial and final moisture distribution data, and distribution of drying agent in the vapor dried poles from Charges 152, 155 and 156, respectively. These data were obtained by analysis of discs taken from the poles in the following manner:

directly, and drying agent retained by difference between the amount of water removed and the loss from the original to extracted and oven dried weights. The extra discs taken from butt and top of the green poles were oven dried whole and subsequently used for density determinations by water soaking and then measuring the volumes by displacement in a water trough. Since the moisture content values for these whole discs were available the results have been included in the tables as checks on moisture content of the zoned discs. The italicized figures showing initial moisture content of the discs taken after vapor drying were obtained from a linear plot of the butt and top green moisture content values against distance from the butt. Such graphs of the average moisture content of the green charges are shown in Figures 7A, 7B, and 7C. These figures show



One disc from each of the points of sectioning was zoned at intervals of one inch into annuli representing the outer inch, second inch, and so on, depending on the diameter of the poles, leaving a solid center section as the remainder of the disc. The zones from the green poles were oven dried to determine moisture content, while those from the vapor dried poles were extracted with toluene to determine water

an increase in moisture content from butt to top for all of the charges. This has been found to be true in the case of the individual poles also. Furthermore, an increase from butt to top will be found by plotting the moisture content data for individual zones, except the remainder, in each of the poles in the charges, with the exception of pole No. 1 in Charge 155 which had very thin sapwood. When the zoned disc

data are plotted in this manner it will be also seen that in the outer zones the percentage increase in moisture content from butt to top is fairly uniform in the poles, as indicated by the fact that the slopes of the lines connecting butt and top moisture content values are much the same. The data so plotted also show decreasing moisture content from the outer zones, toward the center. If the initial and final moisture content values shown at the right of Tables 5: A, B, and C are compared with those shown in Table 2 for the given charges, it will be seen that some discrepancy exists between the data reported in the two tables as shown below:

leveling of the lengthwise gradient by vapor drying. This leveling of the gradient is evidently the result of increasing drying rate toward the top of the poles produced by decreasing diameter. In Figures 8A, 8B and 8C are plotted the radial moisture gradients found in the poles before and after vapor drying. The final moisture content values have been adjusted percentage-wise on the basis of the relation of the initial moisture content of the zones, to the average initial moisture content for the whole poles shown at the right in Table 5. This was done in order to present the data so that the gradients at different points

AVERAGE MOISTURE CONTENT, % OF OVEN DRY WEIGHT

	Average Moisture Content, % of Oven Dry Weight			
	Initial		Final	
	Table 1	Table 5	Table 2	Table 5
Charge No. 152	91.2	83.7	40.5	44.0
" " 153	95.1	100.8	33.5	38.0
" " 154	96.7	95.6	49.7	54.3

In the case of Charge No. 152 this discrepancy is caused partly by the fact that 5 other poles were in the charge for which zoned moisture content values were not obtained. The average moisture content values in Table 2 were calculated using a density value that was an average as determined by moisture content and initial green weight, and as determined by displacement tests. The explanation of the slightly higher final moisture content values in Table 5 than in Table 2 is that the effect of end drying is not included in the latter.

An inspection of the average moisture distribution values for the vapor dried charges in Figures 7: A, B, and C, shows considerable

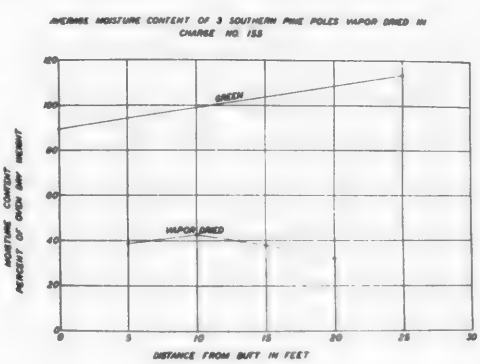

AVERAGE MOISTURE CONTENT OF 3 SOUTHERN PINE POLES VAPOR DRIED IN CHARGE NO. 153
GREEN
VAPOR DRIED
MOISTURE CONTENT PERCENT OF OVEN DRY WEIGHT
DISTANCE FROM BUTT IN FEET

Fig. 7B.

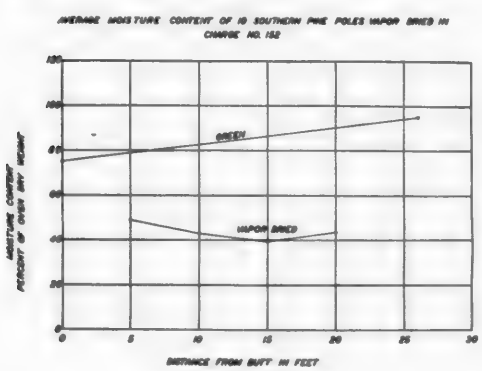

AVERAGE MOISTURE CONTENT OF 10 SOUTHERN PINE POLES VAPOR DRIED IN CHARGE NO. 152
GREEN
VAPOR DRIED
MOISTURE CONTENT PERCENT OF OVEN DRY WEIGHT
DISTANCE FROM BUTT IN FEET

Fig. 7A.

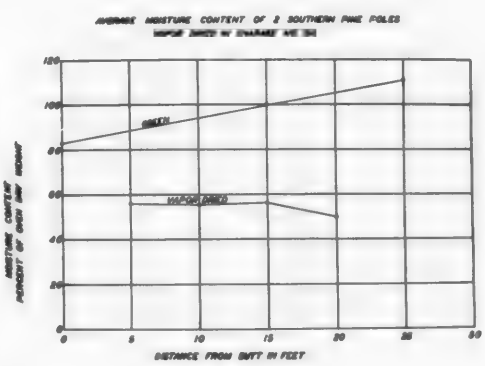

AVERAGE MOISTURE CONTENT OF 2 SOUTHERN PINE POLES
GREEN
VAPOR DRIED
MOISTURE CONTENT PERCENT OF OVEN DRY WEIGHT
DISTANCE FROM BUTT IN FEET

Fig. 7C.

TABLE 5A.—DISTRIBUTION OF MOISTURE AND DRYING AGENT IN SOUTHERN PINE POLES VAPOR DRIED IN CHARGE NO. 152

Moisture Content % of Oven Dry Weight

Pole No.	Condition	Discs from Butt of Green Poles: 1st Inch	2nd Inch	Rem.	Weighted Avg.	Whole Disc	Avg. 2 Discs	Discs from Vapor Dried Poles Taken at Distances from Butt, Shown Below: 5 Ft. 1st Inch	5 Ft. 2nd Inch	5 Ft. Rem.	5 Ft. Weighted Avg.	10 Ft. 1st Inch	10 Ft. 2nd Inch	10 Ft. Rem.	10 Ft. Weighted Avg.	15 Ft. 1st Inch	15 Ft. 2nd Inch	15 Ft. Rem.	15 Ft. Weighted Avg.
1	Green	64.9	79.1	75.5	70.8	72.7	71.7	66.0	84.3	70.0	74.4	69.2	89.3	64.7	77.1	71.4	94.[illegible]	59.4	80.0
	Vapor Dried	-----	-----	-----	-----	-----	-----	39.3	65.5	46.9	49.0	25.4	69.2	38.3	40.3	24.6	69.5	35.1	38.3
2	Green	76.2	75.5	44.3	70.6	69.1	69.9	79.1	78.3	49.1	74.1	81.0	81.2	53.8	78.4	84.8	84.1	58.6	82.7
	Vapor Dried	-----	-----	-----	-----	-----	-----	30.9	59.3	39.0	41.4	23.7	58.0	30.6	34.8	23.4	59.7	31.5	34.9
3	Green	70.6	85.6	91.7	78.7	73.3	76.0	74.7	89.4	87.0	79.2	78.8	93.4	82.5	82.3	82.9	97.4	78.0	85.6
	Vapor Dried	-----	-----	-----	-----	-----	-----	40.3	90.0	95.6	63.4	25.7	57.3	51.3	38.1	30.8	72.2	54.0	45.0
8	Green	86.0	95.6	89.8	89.7	94.4	92.1	88.5	100.0	91.2	94.7	91.0	104.3	92.8	97.4	93.7	108.7	94.3	100.0
	Vapor Dried	-----	-----	-----	-----	-----	-----	43.2	94.1	102.5	66.8	40.8	75.9	92.4	57.9	28.9	75.5	94.4	47.8
10	Green	67.3	67.6	64.1	66.9	63.9	65.4	72.2	72.4	63.2	69.9	78.3	77.3	62.5	74.2	82.0	82.0	61.8	78.7
	Vapor Dried	-----	-----	-----	-----	-----	-----	21.6	50.6	60.4	36.3	21.1	49.0	56.1	34.4	17.1	43.4	44.9	28.1
Average	Green	73.0	80.7	73.1	75.3	74.7	75.0	76.1	84.9	72.1	78.5	79.7	89.1	71.3	81.9	83.0	93.3	70.4	85.4
	Vapor Dried	-----	-----	-----	-----	-----	-----	35.1	71.9	68.9	51.4	27.3	61.9	53.7	41.1	25.0	64.1	52.0	38.8

*Drying Agent Content % of Oven Dry Weight

1	-----	-----	-----	-----	-----	-----	T**	0.6	1.0	0.3	T	T	4.8	0.6	0.6	T	4.0	0.
2	-----	-----	-----	-----	-----	-----	1.4	T	T	0.8	3.2	T	T	1.9	2.1	T	T	1.3
3	-----	-----	-----	-----	-----	-----	T	T	T	T	4.2	T	T	2.4	2.9	T	T	1.8
8	-----	-----	-----	-----	-----	-----	T	T	T	T	T	T	T	T	T	T	T	T
10	-----	-----	-----	-----	-----	-----	0.3	T	2.1	0.5	T	T	0.9	0.1	0.5	T	6.9	0.9
Average	-----	-----	-----	-----	-----	-----	0.3	0.1	0.6	0.3	1.5	T	1.1	1.0	1.2	T	2.3	0.9

Overall Average 0.28 Lbs./Cu. Ft.

*Total Extractives Other Than Water.
**T—Trace or Slight Negative Value.

TABLE 5A.—DISTRIBUTION OF MOISTURE AND DRYING AGENT IN SOUTHERN PINE POLES VAPOR DRIED IN CHARGE NO. 152 (Continued)

Pole No.	Condition	Discs from Vapor Dried Poles Taken at Distances from Butt, Shown Below 20 Ft. 1st Inch	2nd Inch	Rem.	Weighted Avg.	Discs from Top of Green Poles 1st Inch	2nd Inch	Rem.	Weighted Avg.	Whole Disc	Avg. 2 Discs	Average for 5 Foot Sections of Vapor Dried Poles 1st Inch	2nd Inch	Rem.	Weighted Avg.
1	Green	73.7	101.4	54.2	82.8	75.9	104.2	49.0	82.0	89.3	85.6	70.1	92.3	62.1	78.6
	Vapor Dried	36.8	84.5	51.1	51.3	-----	-----	-----	-----	-----	-----	31.5	72.2	42.9	44.7
2	Green	87.7	87.0	63.4	87.0	90.5	90.0	68.2	89.0	93.3	91.2	83.2	82.7	56.2	80.6
	Vapor Dried	34.2	68.7	53.7	48.4	-----	-----	-----	-----	-----	-----	28.1	61.4	38.7	39.9
3	Green	87.3	101.4	73.6	88.8	91.3	105.5	74.1	93.6	90.5	92.1	80.9	95.4	80.3	84.0
	Vapor Dried	29.8	72.9	22.9	41.9	-----	-----	-----	-----	-----	-----	31.7	73.1	56.0	47.1
8	Green	96.1	113.1	96.0	102.6	98.6	117.3	97.7	103.0	107.5	105.3	92.3	106.5	93.6	98.7
	Vapor Dried	31.8	76.2	124.0	49.1	-----	-----	-----	-----	-----	-----	36.2	80.4	103.3	55.4
10	Green	87.0	86.8	61.1	83.1	92.0	91.6	60.5	89.1	86.5	87.8	79.9	79.6	62.2	76.5
	Vapor Dried	21.8	49.4	44.1	32.3	-----	-----	-----	-----	-----	-----	30.4	48.1	51.4	32.8
Average	Green	86.4	97.9	69.7	88.9	89.7	101.7	69.9	91.3	93.4	92.4	81.3	91.3	70.9	83.7
	Vapor Dried	30.9	70.3	59.2	44.6	-----	-----	-----	-----	-----	-----	29.6	67.0	58.5	44.0
		*Drying Agent Content % of Oven Dry Weight													
1		2.0	T	T	1.3	-----	-----	-----	-----	-----	-----	0.7	0.2	2.5	0.7
2		T	T	0.1	0.1	-----	-----	-----	-----	-----	-----	1.7	T	T	1.0
3		6.8	T	T	4.1	-----	-----	-----	-----	-----	-----	3.5	T	T	2.1
8		T	T	T	T	-----	-----	-----	-----	-----	-----	T	T	T	T
10		T	T	1.1	0.9	-----	-----	-----	-----	-----	-----	0.2	T	3.8	0.6
Average		1.8	T	0.2	1.3	-----	-----	-----	-----	-----	-----	1.2	0.1	1.1	0.9

Overall Average 0.28 Lbs./Cu. Ft.

*Total Extractives Other Than Water.
**T—Trace of Slight Negative Value.

TABLE 5B.—DISTRIBUTION OF MOISTURE AND DRYING AGENT IN SOUTHERN PINE POLES VAPOR DRIED IN CHARGE NO. 155

Moisture Content % of Oven Dry Weight

Pole No.	Condition	Discs from Butt of Green Poles: 1st Inch	2nd Inch	3rd Inch	4th Inch	Rem.	Weighted Avg.	Whole Disc	Av. 2 Discs	Discs from Vapor Dried Poles Taken at Distances from Butt, Shown Below: 1st Inch	2nd Inch	5 Ft. 3rd Inch	4th Inch	Rem.	Weighted Avg.	1st Inch	2nd Inch	10 Ft. 3rd Inch	4th Inch	Rem.	Weighted Avg.	1st Inch	2nd Inch	15 Ft. 3rd Inch	4th Inch	Rem.	Weighted Avg.
1	Green	105.1	64.8	33.5	31.0	31.7	60.9	60.7	60.8	106.8	65.3	33.2	30.4	31.2	62.4	108.6	65.8	32.9	29.8	30.6	63.9	110.3	66.4	32.5	29.3	30.1	65.5
	Vapor Dried	-----	-----	-----	-----	-----	-----	-----	-----	4.8	17.6	30.3	30.5	29.8	17.9	4.4	17.3	30.0	31.0	27.9	17.2	4.4	16.5	29.2	30.9	29.0	16.8
2	Green	155.3	123.9	95.1	46.6	24.5	95.4	101.8	98.6	160.1	132.2	104.7	53.2	24.8	105.3	165.0	140.5	114.4	59.8	25.2	115.2	169.8	148.9	124.0	66.3	25.5	125.0
	Vapor Dried	-----	-----	-----	-----	-----	-----	-----	-----	33.4	75.1	96.0	49.4	29.0	57.3	40.3	96.4	109.5	56.1	29.4	68.7	32.2	82.3	104.5	47.0	27.9	60.5
3	Green	134.6	122.4	115.7	100.9	49.9	107.3	106.9	107.1	140.0	126.3	121.7	103.2	47.5	111.4	145.3	130.2	127.7	105.6	45.1	115.5	150.7	134.1	133.6	107.9	42.6	119.6
	Vapor Dried	-----	-----	-----	-----	-----	-----	-----	-----	28.4	45.8	55.1	56.6	34.2	41.9	27.5	46.1	54.2	50.6	34.2	41.1	26.8	43.1	80.4	46.8	30.1	38.2
Average	Green	131.7	103.7	81.4	62.2	35.4	87.9	89.8	88.8	135.6	107.9	86.5	62.3	34.5	93.0	139.6	112.2	91.7	65.1	33.6	98.2	143.6	116.5	96.7	67.8	32.7	103.4
	Vapor Dried	-----	-----	-----	-----	-----	-----	-----	-----	22.2	46.2	60.5	45.5	31.0	39.0	24.1	53.3	64.6	45.9	30.5	42.3	21.1	47.3	61.4	41.6	29.0	38.5

*Drying Agent Content % of Oven Dry Weight

1	-----	-----	-----	-----	-----	-----	-----	1.0	T**	T	T	T	0.3	1.2	T	T	T	0.8	0.5	1.7	T	T	T	T	0.6
2	-----	-----	-----	-----	-----	-----	-----	13.3	8.9	T	1.8	T	6.3	12.3	2.1	T	T	T	4.3	14.5	1.2	T	1.8	2.4	8.2
3	-----	-----	-----	-----	-----	-----	-----	T	T	T	T	T	T	T	T	T	T	0.7	0.1	T	T	T	T	2.4	0.3
Average	-----	-----	-----	-----	-----	-----	-----	4.8	3.0	T	0.6	T	2.2	4.5	0.7	T	T	0.5	1.6	5.4	3.7	T	0.6	1.6	3.0

Pole No.	Condition	Discs from Vapor Dried Poles Taken at Distances from Butt, Shown Below: 1st Inch	2nd Inch	20 Ft. 3rd Inch	4th Inch	Rem.	Weighted Avg.	Discs from Top of Green Poles: 1st Inch	2nd Inch	3rd Inch	4th Inch	Rem.	Weighted Avg.	Whole Disc	Av. 2 Discs	Avg. for 5 Foot Sections of Vapor Dried Poles: 1st Inch	2nd Inch	3rd Inch	4th Inch	Rem.	Weighted Avg.
1	Green	112.1	66.9	32.2	28.7	29.5	67.0	113.8	67.4	31.9	28.1	29.0	68.5	70.9	69.7	109.5	66.1	32.7	29.6	30.4	64.7
	Vapor Dried	4.6	17.5	28.4	28.4	26.0	16.2	-----	-----	-----	-----	-----	-----	-----	-----	4.6	17.2	29.5	30.2	28.2	17.0
2	Green	174.7	157.2	133.7	72.9	25.9	134.9	179.5	165.5	143.3	79.5	26.2	144.8	140.2	142.5	167.4	144.7	119.2	63.1	25.4	120.1
	Vapor Dried	8.8	42.4	99.7	58.4	26.9	42.5	-----	-----	-----	-----	-----	-----	-----	-----	28.7	74.1	102.4	52.7	28.3	57.3
	Green	156.0	138.0	139.6	110.3	40.2	123.7	161.4	141.9	145.6	112.6	37.8	127.8	122.5	125.2	148.0	132.2	130.7	106.8	43.9	117.6
	Vapor Dried	24.8	43.2	51.5	44.0	29.7	37.4	-----	-----	-----	-----	-----	-----	-----	-----	26.9	44.6	52.8	49.5	32.1	39.7
Average	Green	147.6	120.7	101.8	70.6	31.9	108.5	151.6	124.9	106.9	73.4	31.0	113.7	111.2	112.5	141.6	114.3	94.2	66.5	34.4	100.8
	Vapor Dried	12.7	34.4	59.9	43.6	27.5	32.0	-----	-----	-----	-----	-----	-----	-----	-----	20.1	45.3	61.6	44.1	29.5	38.0
1	-----	1.8	T	T	3.0	9.1	1.3	-----	-----	-----	-----	-----	-----	-----	-----	1.4	T	T	0.8	2.3	0.7
2	-----	12.8	14.0	3.1	0.3	9.5	8.9	-----	-----	-----	-----	-----	-----	-----	-----	13.2	9.0	0.8	1.0	3.0	6.9
3	-----	1.1	T	T	T	0.2	0.4	-----	-----	-----	-----	-----	-----	-----	-----	0.3	T	T	T	0.8	0.2
Average	-----	5.2	4.7	1.0	1.1	6.3	3.5	-----	-----	-----	-----	-----	-----	-----	-----	5.0	3.0	0.3	0.6	2.0	2.6

Overall Average—0.73 Lbs./Cu. Ft.

*Total Extractives Other Than Water.
**T—Trace or Slight Negative Value.

TABLE 5C.—DISTRIBUTION OF MOISTURE AND DRYING AGENT IN SOUTHERN PINE POLES VAPOR DRIED IN CHARGE NO. 156

Moisture Content % of Oven Dry Weight

Pole No.	Condition	Discs from Butt of Green Poles: 1st Inch	2nd Inch	3rd Inch	4th Inch	Rem.	Weighted Avg.	Whole Disc	Av. 2 Discs	Discs from Vapor Dried Poles Taken at Distances from Butt, Shown Below: 1st Inch	2nd Inch	5 Ft. 3rd Inch	4th Inch	Rem.	Weighted Avg.	1st Inch	2nd Inch	10 Ft. 3rd Inch	4th Inch	Rem.	Weighted Avg.	1st Inch	2nd Inch	15 Ft. 3rd Inch	4th Inch	Rem.	Weighted Avg.
1	Green	106.5	98.5	93.0	74.7	37.6	78.8	78.3	78.6	113.5	105.0	100.5	76.3	35.9	83.7	120.6	111.5	108.0	77.9	34.2	88.7	127.6	118.0	115.6	79.5	32.4	93.6
	Vapor Dried	-----	-----	-----	-----	-----	-----	-----	-----	30.6	78.7	77.0	62.3	36.8	54.6	17.1	73.6	78.4	55.4	35.8	49.9	28.7	78.5	81.8	49.2	32.8	53.2
2	Green	105.3	96.3	92.8	90.0	45.0	82.5	94.3	88.4	114.1	105.3	100.0	94.6	44.8	89.4	122.9	113.7	107.2	99.3	44.6	96.4	131.7	122.2	114.4	103.9	44.5	103.3
	Vapor Dried	-----	-----	-----	-----	-----	-----	-----	-----	33.2	74.3	77.1	74.9	40.8	57.4	30.8	75.8	85.5	84.2	45.8	60.8	26.4	74.6	84.2	84.2	41.2	59.1
Average	Green	105.9	97.7	92.9	82.4	41.3	80.7	86.3	83.5	113.8	105.2	100.3	85.5	40.4	86.6	121.8	112.6	107.6	88.6	39.4	92.6	129.7	120.1	115.0	91.7	38.5	98.5
	Vapor Dried	-----	-----	-----	-----	-----	-----	-----	-----	32.9	76.5	77.1	68.6	38.8	56.0	24.0	74.7	82.0	69.8	40.8	55.4	27.6	74.6	83.0	66.7	37.0	56.2

*Drying Agent Content % of Oven Dry Weight

1	-----	-----	-----	-----	-----	-----	-----	-----	3.7	T**	T	T	T	0.9	5.3	0.4	T	T	T	1.6	3.6	T	1.6	1.1	0.9	1.6
									1.5	T	T	T	2.1	0.9	1.9	T	T	T	T	0.5	2.2	T	T	T	0.6	0.7
2	-----	-----	-----	-----	-----	-----	-----	-----																			
Average	-----	-----	-----	-----	-----	-----	-----	-----	2.6	T	T	T	1.1	0.9	3.6	0.2	T	T	T	1.1	2.9	T	0.8	0.6	0.8	1.2

Pole No.	Condition	Discs from Vapor Dried Poles Taken at Distances from Butt, Shown Below: 1st Inch	2nd Inch	20 Ft. 3rd Inch	4th Inch	Rem.	Weighted Avg.	Discs from Top of Green Poles: 1st Inch	2nd Inch	3rd Inch	4th Inch	Rem.	Weighted Avg.	Whole Disc	Av. 2 Discs	Avg. for 5 Foot Sections of Vapor Dried Poles: 1st Inch	2nd Inch	3rd Inch	4th Inch	Rem.	Weighted Avg.
1	Green	134.7	124.5	123.1	81.1	30.7	98.6	141.7	131.0	130.6	82.7	29.0	103.5	105.4	104.5	124.1	114.8	111.8	78.7	33.3	91.2
	Vapor Dried	17.7	69.4	74.3	51.0	32.6	47.2	-----	-----	-----	-----	-----	-----	-----	-----	23.5	75.1	77.9	54.5	34.5	51.2
2	Green	140.5	130.6	121.6	108.6	44.3	110.3	149.3	139.1	128.8	113.2	44.1	117.2	119.8	118.5	127.3	118.0	110.8	101.6	44.6	99.9
	Vapor Dried	18.5	69.3	79.5	71.4	36.2	52.3	-----	-----	-----	-----	-----	-----	-----	-----	27.2	73.5	81.6	78.7	41.0	57.4
Average	Green	137.6	137.6	122.4	94.9	37.5	104.5	145.5	135.1	129.7	98.0	36.6	110.4	112.6	111.5	125.7	116.4	111.3	90.2	39.0	95.6
	Vapor Dried	18.1	69.4	76.9	61.2	34.4	49.8	-----	-----	-----	-----	-----	-----	-----	-----	25.4	74.3	79.8	66.6	37.8	54.3
1	-----	4.4	0.4	T	T	T	1.4	-----	-----	-----	-----	-----	-----	-----	-----	4.3	0.2	0.4	0.3	0.2	1.4
		3.4	T	T	T	6.9	2.2	-----	-----	-----	-----	-----	-----	-----	-----	2.2	T	T	T	2.4	1.1
2	-----															3.2	0.1	0.2	0.2	1.3	1.2
Average	-----	3.9	0.2	T	T	3.5	1.8	-----	-----	-----	-----	-----	-----	-----	-----	Overall Average—0.36 Lbs./Cu. Ft.					

*Total Extractives Other Than Water.
**T—Trace or Slight Negative Value.

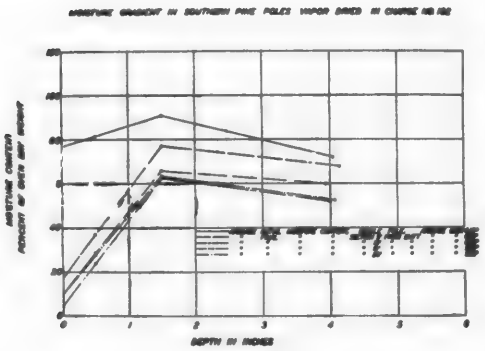


Fig. 8A.

along the pole could be compared with the average initial moisture content value and with each other on a single chart for each charge. From these figures it will be seen that the shape of the moisture distribution curves is remarkably consistent along the length of the poles in a given charge, and that the gradients of the outer two inches indicate very low relative humidity in the drying atmosphere. The fact that in Charge 156 the boundary conditions indicated for the 15-foot and 20-foot discs would require negative values for relative humidity is not considered to have resulted from moisture loss in removing the discs, since particular care was taken to prevent this by weighing them immediately after removal from the poles, and after zoning and chipping to obtain corrections for losses that occurred in these operations. These inconsistencies are believed to have developed from the use of the vacuum after heating in vapor. The presence of substantial amounts of condensed drying agent

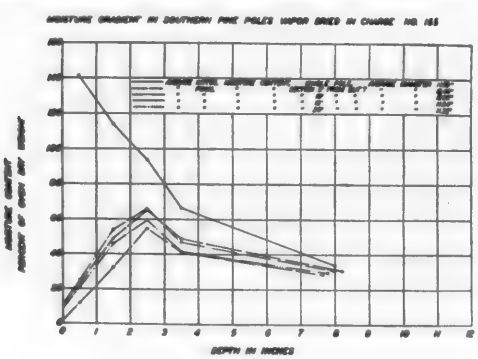


Fig. 8B.

in the outer zone of the wood at the start of the vacuum could prevent re-establishment of equilibrium when the small amount of water present there was vaporized. Because of the use of this vacuum none of the intercepts indicating boundary conditions can be used to estimate accurately the relative humidity during the cycle of heating in vapor, since a substantial amount of the water is vaporized during the vacuum.

The figures for distribution of drying agent in the poles after vapor drying, shown in Table 5 indicate that the retention is very low. Comparison of these overall average values with those determined by method 1, shown in Table 2, reveals fairly good agreement. The drying agent retention values shown in Table 5 are probably somewhat higher than actual since the figures represent total extractives other than

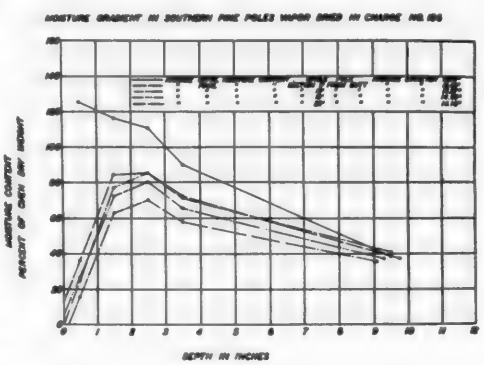


Fig. 8C.

water removed from the wood. Efforts to correct for resins removed by extraction were not considered warranted because of the low values for total extractive.

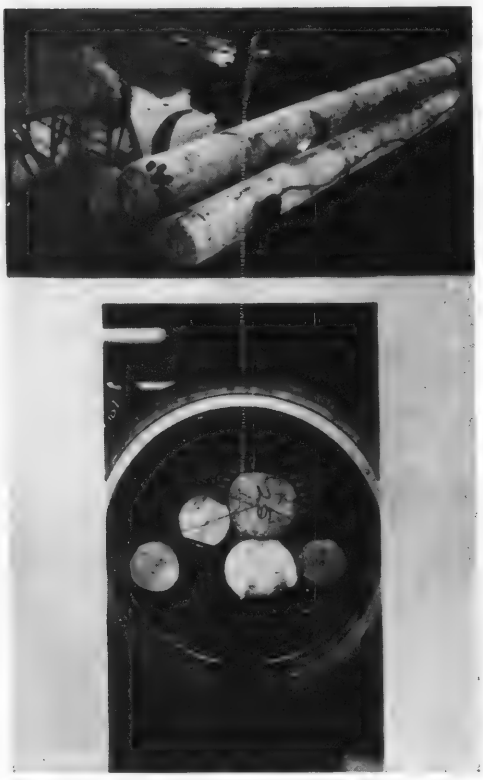
In the accompanying photographs are shown lengthwise views and cross-sections at the point five feet from the butt of the poles vapor dried in Charges 152, 155, and 156. Except for pole No. 1 in Charge 155, it will be seen that practically no checking was produced by the vapor drying. This particular pole, which had a very thin layer of sapwood, was dried to a much lower final moisture content than any of the others, (See Table 5B). The amount of this type of checking that is produced when poles are dried to very low moisture content has been found to be dependent on diameter, the check-

Lengthwise views of poles after vapor drying in Charges 152, 155 and 156.

ing being greater in those of larger diameter. With the type of drying cycle described in this paper, such checking only begins to appear in sawn timbers, dried to 4 percent moisture content, when the thickness exceeds about 3 inches. When thicker material is to be dried to this moisture content, it is necessary to employ a drying cycle in which periods of heating in vapor are interrupted by intervals of vacuum to allow redistribution of moisture, to prevent this checking. The drying preparatory to impregnation, of species having predominantly thin sapwood, such as Douglas Fir, has been carried out without producing checking merely by employing shorter drying cycles than those normally used for Southern Pine.

For purposes of studying the internal temperatures developed in the wood during vapor drying, it was necessary to devise a method for insertion of thermocouples other than the generally accepted one described by MacLean (8). Aside from the physical difficulty of boring 25 foot poles from the end, to insert the thermocouples, and bolting them between the metal end plate and the cylinder door; the major obstacle preventing the use of this method in vapor drying, is that no gasketing material has been found which is soft enough to effectively seal the ends of the timber, and at the same time remain intact in the vapor of most of the organic drying agents used. These drying agents, particularly those containing high percentages of aromatic hydrocarbons, at high temperature quickly enter into solid solution in various rubbers or other elastomers, causing them to swell and to be extruded from the space between the wood and the metal plates, rendering the seal ineffective. In Figure 9 is shown the method of insertion of thermocouples developed for studies of temperature

Cross sections of poles after vapor drying in Charges 152, 155 and 156.



Views showing arrangement of leadwires to thermocouples in charges ready to be vapor dried.

change in wood during vapor drying. The poles or other timber are bored through at the midpoint and a butt welded couple is inserted and positioned at the desired depth. Short greased, wooden plugs slightly larger than the hole are then driven in from each side leaving a gap at the couple of about $\frac{1}{16}$ inch. Lead wool is then introduced into the holes and impacted by driving down with a metal rod slightly smaller than the hole. After a lead seal of ¼ to ½ inch has been made, more wooden plugs are driven in, then more lead wool until the holes are completely sealed; the last fill at the surface being of lead. Usually 6 thermocouples are inserted at the midpoint of poles at depth intervals of ½ or 1 inch. The holes are spaced along the pole at 2 to 4 inch intervals. The thermocouple lead-wires are led through an insulated fitting in the cylinder wall to a selector switch connected with the potentiometer.

Two of the accompanying photographs show the method used for placing the thermocouple lead-wires on the poles to connect them with the leads passing through the insulated fitting in the cylinder wall. The lead-wires, which are bare, are carried along the pole on knob insulators to the front of the cylinder, where they are connected to the leads that pass through the insulated fitting. These latter leads are protected with fish-spine insulators up to the point where they enter the insulated fitting since they must pass through a short section of one inch pipe to reach it.

Although a considerable amount of data have been amassed relative to internal temperatures attained in wood during vapor drying, this is not yet available in correlated form because of the large number of variables that are involved. The major variables discussed by MacLean (9) in his studies of heating wood in

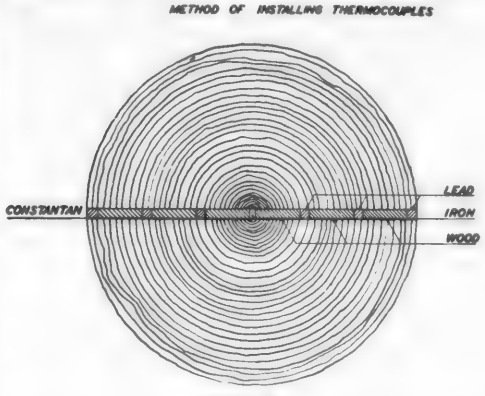


Fig. 9.

various media; viz., the type of heating medium and its temperature; cross-section, condition of seasoning, and specific gravity of the specimen being heated; are likewise encountered in vapor drying. However, in the case of vapor drying the complexity of the effects of these variables is greater than that demonstrated in most of his work, with the possible exception of his studies of temperature changes in green wood heated in creosote under vacuum (10), (11). In vapor drying, change in temperature with time is materially affected by the moisture content of the wood since large quantities of water are

evaporated during heating which keeps the temperature depressed. Moreover the effect of this variable differs with species and also with wood structure within a given species, since the rates of loss of moisture, at given moisture content, vary. Moisture loss from porous species is very rapid, and the internal termperature will therefore remain lower than in species that offer greater resistance to passage of water to the surface. From the standpoint of temperature observations only, the relatively low values found in wood during vapor drying would indicate low rate of heat transfer, but when the amount of vaporization of water is taken into consideration it will be seen that the heat transfer rate is very high. The large amount of heat released by the condensing vapor and the intimate contact with the wood both act to produce high rates of heat transfer. The absence of stable or slowly moving films of liquid at the surface of the wood, such as are present when it is immersed in liquids for heating, is believed to be an additional factor acting to increase the heat transfer rate.

In Figure 10 are shown the averaged temperature data obtained during vapor drying of

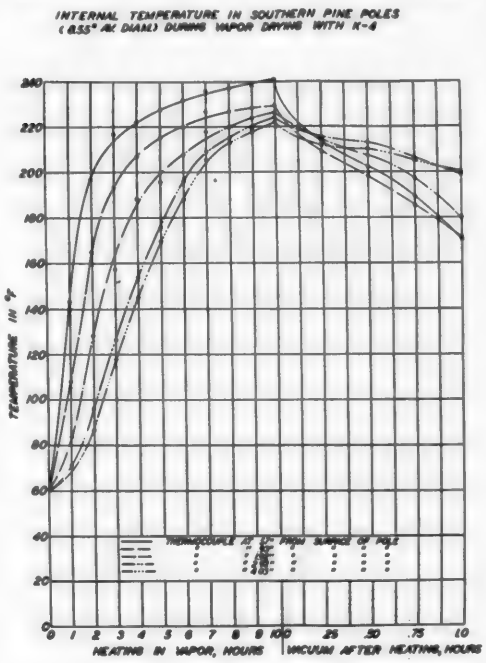

INTERNAL TEMPERATURE IN SOUTHERN PINE POLES
(8.55" AV. DIAM.) DURING VAPOR DRYING WITH K-4
TEMPERATURE IN °F
HEATING IN VAPOR, HOURS
VACUUM AFTER HEATING, HOURS

Fig. 10.

6 thermocouple poles placed in Charges 216, 217, 224, 233, 235 and 238. Data for the individual charges are shown in Table 2. The thermocouple poles had an average diameter of 8.55 inches, and an average initial moisture content of 67.2 percent. The average temperature of the vapor surrounding the poles during drying was 308° F. From the curves of Figure 10 it will be seen that the temperature of the

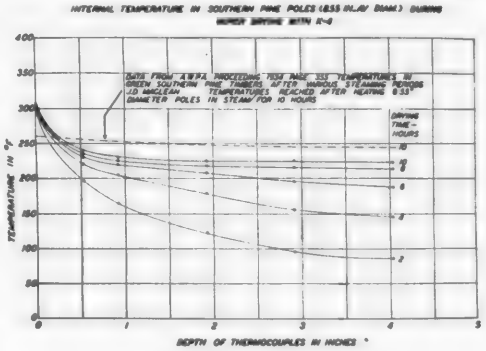


Fig. 11.

wood remained well below that of the vapor throughout the heating period and except for the outer half inch tended to reach equilibrium at about 230° F. It will also be noted that during the vacuum after heating in vapor a reversal of the temperature pattern occurred, which shows that the vaporization of remaining water was greatest in the outer zones.

The data of Figure 10 have been plotted in Figure 11 to show the relation of depth of thermocouples to temperature after various periods of heating in vapor. Data for heating pine poles of this diameter in steam at 260° F. for 10 hours are also shown in Figure 11 for purposes of comparison. The fact that in vapor drying, the wood temperatures remain at or near the boiling point of water as long as much water is present is considered to account for the substantial difference in strength found between vapor dried and steamed poles reported by Hudson (7). The fact that hydrolysis, which appears to be the chief cause of reduction of strength by steaming, proceeds at rates governed by both temperature and concentration of water, points to this conclusion. The possibility that the relatively low temperatures observed in the wood, during vapor drying, might be the result of the method of insertion of

thermocouples has been considered, but the only questionable point that has been raised regarding the method is one that would indicate that the observed temperatures are higher than they should be. This has to do with the fact that the wooden plugs, used to seal the thermocouples in, are situated with the grain in the direction of heat flow, and since the rate of heat flow longitudinally in wood is about twice that occurring in the radial and tangential directions, it might be possible that the temperatures recorded are higher than they would be in the normal wood. This factor, however, is not considered as significant because of the film resistances, afforded by the discontinuity of make-up of the seals, to heat transfer in this manner. The question of the ability of the seals to prevent the escape of steam which would result in low temperature readings has been examined also. In testing this, thermocouple holes in pole sections were sealed from one side only, and air pressure applied from a line driven into the other. Application of enough pressure to cause air to pass to the surface of the specimens around the circumference was not sufficient to cause leakage of the thermocouple seals. That the seals remain intact during the vapor drying operation is indicated by the fact that the inner couples remain at higher temperature than the outer ones during the vacuum, showing that the pressure does not equalize rapidly which would be the case if leaks were present.

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FOREST PRODUCTS RESEARCH SOCIETY

Aspects of Kiln Design

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IN ORDER to appreciate the features embodied in the design and equipment of a modern kiln, the objectives desired and the problems involved in drying should be thoroughly understood. The first objective in drying lumber is to preshrink it to a definite moisture content uniformly throughout the kiln, so that subsequent exposure to atmospheric conditions will cause a minimum change in dimensions. The second objective is to avoid loss of material due to improper treatment that will produce checks, honeycomb, undue warpage and non-uniform moisture content. Improper moisture content is the most insidious defect of all, in that it can get through in the finished product to the consumer and cause loss of business. The third objective is to have low operating cost for steam, electrical power, lumber handling, and investment per 1000 board feet.

To meet the above objectives, specifications covering kiln design and equipment should call for:

1. Control of the dry- and wet-bulb temperatures exactly at the point where the air enters the load.
2. Uniform conditions, both as to temperatures and air volume, from one end of the kiln to the other.
3. No longitudinal drift of the heat and humidity.
4. An adequate air volume, in order to minimize the temperature drop or drying lag across the width of a load.
5. The most efficient method of delivering the necessary circulation to get the lowest possible power cost for fan drive.
6. Minimum steam consumption, by using automatic ventilation and large holding capacity per cubic foot of building, plus fast drying.
7. Large loads put up without flues or spaces between the edges of the boards, to give low-cost stacking and handling.

Various designs and classes of equipment have been used, all striving to meet such specifications as these. The natural-draft type was the most predominant of the earlier kilns, but open stacking of the lumber plus slow and indefinite air movement with no place to accurately control entering air conditions left much to be desired in this type of kiln. External-pressure blower types were an improvement, but the movement of large air volumes through delivery and return ducts causes high static and consumes a large amount of power per 1000 feet of air delivered. Furthermore, the stacking with A-shaped chimneys in the load had to be accurate for proper air delivery and so was costly and reduced kiln holding capacity.

The need for large volumes of air moving through large loads was recognized about 1923 and, in order to reduce power cost, the internal-fan kiln was invented. By distributing disc fans in the kiln, air was delivered through the lumber at about ⅛-inch static pressure, as compared to about one inch in the external-blower type. Loads could also be stacked with boards edge to edge, thus increasing kiln holding capacity and reducing stacking and handling costs. Drying times were decreased, due to the large air volumes delivered at low power cost, and the combined result of large holding capacity and fast drying gave low cost for drying and investment. The internal-fan kiln consequently became the type in general use, both for new kilns and for remodelling of natural draft types.

The first internal-fan kiln had all the fans clamped at about 8-foot intervals on a long shaft extending lengthwise of the kiln. Large disc fans of the reversing type, such as used in

mines, were all that were used. In this type of construction, the fans face lengthwise of the kiln and the air, as it leaves the fans, moves lengthwise so that deflecting ducts and baffles must be used to turn the air crosswise. Consequently, there is a certain lack of uniformity of air delivery and a consumption of power due to line shafts, deflecting ducts, and the blowing of fans directly into one another in an attempt to eliminate end drift of the heat and humidity. The end drift of the air currents causes wide variations in temperatures.*

The latest development in kiln design follows the principle of the internal-fan type, differing mainly in the placement of the fans and the method of driving them. The first step toward eliminating end drift of the heat and humidity and also giving uniform air delivery was to face the fans toward the side wall and use a straight-line partition, so that straight drafts of air were delivered crosswise of the kiln. This also gave lower power cost for fan drive by eliminating line shafts and deflecting ducts. The first kilns of this type had short shafts extending to a point outside, where the drives were located.

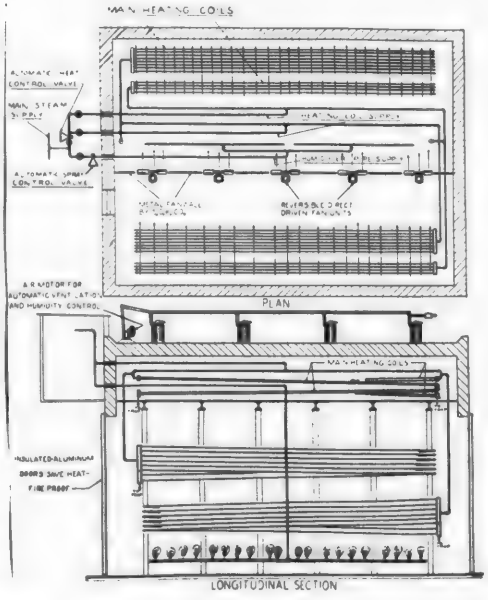
A comparative study of this kiln and a long-shaft kiln was made in this country by Greenhill of the Australian Forest Products Laboratory, who states (1):

> "A more recent arrangement is to have the fans on a number of cross shafts ---------. *From tests made by the Division of Forest Products,* there is every indication that the cross shaft internal fan kiln is the most efficient type of commercial kiln in operation today, *both in regard to uniformity of circulation and to the quantity* of air circulated through the timber per unit power consumption of the fans. *The Division recommends this type of kiln almost exclusively,*-------." (Italics supplied by the author of this paper.)

The development of fibre glass for windings and for other parts of the insulation of motors was started industrially in 1931 and was in production by 1935. This was the material needed to insure proper service from motors inside a kiln. The next step then was to use this material and simplify the drive by putting the motors inside the kiln. As a result of ten years of experience with several thousand such units, it has been proven that they stand up to kiln conditions when properly built and installed.

To quote from that eminent authority, H. D. Tieman (2):

> "Since *circulation* is the key to rapid and uniform drying of wet lumber in any kiln, the economical arrangement of the fans is of prime importance. If the complete units of fan and motor could be placed within the kiln itself, it would be feasible *to do away with ducts and baffles and produce direct straight-line draughts of air just where desired without deflections.*
>
> "An arrangement of direct flow of air through two piles of lumber with a re-heating set of pipe coils between, is certainly very appealing to one's sense of what ought to be. Moreover, the fans can be reversed as desired so that very *uniform drying can be produced.*
>
> "It would seem as though the acme of perfection has about been reached in the design

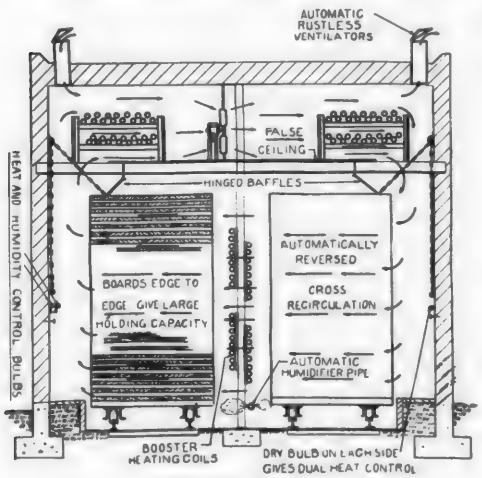


* For details on end drift of air currents and air distribution see Rasmussen, E. F.: Analysis of problems relating to uniformity of kiln control. Mimeograph No. R 1645, U. S. Forest Products Lab., p. 7 (March 1947). Also Thelen Patent, U. S. 1,591,577 and Rankin Patent, U. S. 1,815,798.

and construction of dry kilns; improvements would appear to lie in the schedules used and the pre-treatment accorded the lumber."

The circulating system of the direct driven fan design, with fans facing the side walls, gives all that is desired in uniformity of air delivery at low operating cost. Automatic reversing of the cross circulation also speeds up drying.

The heating system must be designed to give a uniform temperature on the entering-air side, from one end of the kiln to the other. Steam supply headers are placed at opposite ends of the kiln and the supply from the main is brought to the center of the kiln and then branches to each end; in this way the steam enters the supply headers at each end, at the same time and in equal volumes, and flows through the coils in the opposite direction. This counter flow balances up the heat to give uniform temperature the full length of the kiln. Automatic control bulbs, placed in this air stream, accurately control the air entering


AUTOMATIC RUSTLESS VENTILATORS
FALSE CEILING
HINGED BAFFLES
HEAT AND HUMIDITY CONTROL BULBS
BOARDS EDGE TO EDGE GIVE LARGE HOLDING CAPACITY
AUTOMATICALLY REVERSED CROSS RECIRCULATION
AUTOMATIC HUMIDIFIER PIPE
BOOSTER HEATING COILS
DRY BULB ON EACH SIDE GIVES DUAL HEAT CONTROL
CROSS SECTION

the kiln load and this air is uniformly distributed in ample volume to give accurate drying at a fast rate.

For long kilns, a Multizone system of heating and controlling is used to insure uniform temperatures along the length of the kiln. It should be emphasized that uniform temperatures and air distribution are functions of production as well as quality.

The multizone kiln has an independent heating coil at each end and a Multizone Recorder Controller with two independent dry-bulb systems for independent temperature control of each end of the kiln, insuring uniform temperature and humidity control throughout the length of the kiln. A third (wet) bulb provides humidity control for the kiln. All three temperatures are continuously recorded on one chart. Each dry-bulb system has two bulbs, one on each side of the kiln, to insure correct entering air temperature for the load, whichever way the fans are blowing. Duplex damper control operates the ventilator dampers independently of the steam sprays.

With this design and equipment, the most exacting kiln schedules can be followed to dry any species of wood green from the saw, or to air seasoned stock to a uniform final moisture content at highest quality and at lowest cost, both for operating and investment.

The features of design and equipment are shown in the accompanying figures.

References

(1) Greenhill, W. L.: The design of the circulating system of commercial timber seasoning kilns. Australian Council for Scientific and Industrial Research, Vol. 10, No. 2, May 1937. Division of Forest Products Reprint No. 41.

(2) Tiemann, H. D.: The kiln drying of lumber. J. B. Lippincott Co.

Discussion

Mr. J. M. McMillen (U. S. Forest Products Laboratory): The Forest Products Laboratory has made tests on several long-shaft kilns with alternately-opposed fans and found that the longitudinal air-drift problem has been overcome.

Mr. Alan Gordon (Food and Agriculture Organization of United Nations): As an Australian, with several years of experience with the CSIR, Division of Forest Products, the organization to which Mr. Greenhill belonged, I would like to say a few words about season-

ing in Australia, which I think should be of interest. Our native forests provide us with an output which is quite different from that in the United States and Canada. We produce from our native forests perhaps 75 percent hardwoods, most of which belong to a genus *Eucalyptus*. These woods are characterized by being difficult to season and until the early twenties many of them were not well regarded for uses other than rough carpentry. This is associated with difficulty in seasoning and susceptibility to excessive shrinkage or collapse. Early in the 1920's Mr. Tiemann spent a period in Australia, during which kiln drying was put on a satisfactory basis, but only on a small scale. Kiln drying there has been developed through the stages of natural circulation, longitudinal shaft and now, I believe, all the new installations are of the cross-shaft internal fan type. A great impetus on seasoning in Australia, both by air drying and kiln drying, has been given by the Division of Forest Products since its establishment in 1928. The number of kiln installations now approaches 1000 and generally speaking the seasoning of hardwoods and softwoods in Australia is of a high standard.

Tungsten Carbide Use in the Woodworking Industry

M. A. Corti
President, Marcoloy, Inc., Springdale, Conn.

TUNGSTEN carbide is a newcomer to the woodworking field. It has some great successes to its credit—and some failures. Most of the failures that I have observed can be attributed to poor tool engineering or to hap-hazard applications. On the chance that some of you may not know specifically just what tungsten carbide is, let's start with a definition. Tungsten carbide is an alloy and a product of powder metallurgy. It is not to be confused with steel or with the tungsten steels. It is the hardest material ever made by man and is next to the diamond in hardness. It might me termed a "man-made diamond." It is so hard that only the diamond will cut it efficiently and its qualities are not unlike those of the diamond.

To make tungsten carbide, metal carbide powders are blended together, then compressed into shapes, and cemented at extremely high temperatures (in the neighborhood of 3000 degrees F. under inert atmospheres). With this over-simplified definition, let's discuss its practical applications. I could spend the time allotted in discussing the scientific aspects of tungsten carbide, but time will only permit a brief discussion of its practical uses in your industry, its advantages and limitations, and the economics of its application in the woodworking field.

First, let's look at the properties of tungsten carbide which will make it an invaluable cutting tool in the woodworking field. Tungsten carbide knives will stay sharp many, many times longer than steel knives. It will cut across the grain readily. It will cut the hardest woods. Because of its high resistance to abrasion, tungsten carbide will cut through mineral streaks, glue lines and veneers of all description, hour after hour, day after day. It opens up new horizons in speeds, making it possible to use high-frequency power turning cutter heads at 20,000 to 50,000 R. P. M., which in turn offers new objectives to the machine designers and builders.

Fortunately, the woodworking industry can avoid the pioneering and experimental engineering work which evolves with the use of a revolutionary product such as tungsten carbide, because all of this initial work has been done in other industries. This is not to imply that all problems have been solved, but they will be minor ones if the basic fundamentals of tungsten carbide tool engineering are adhered to.

Tungsten carbide is a natural application for shaper knives, moulders, stickers, glue jointers, tenoners, routers and saws, and with each application sound engineering should be adhered to. Let us discuss the shaper application, for instance, either hand-operated or automatic, where shaper steel knives are commonly used. Simply applying tungsten carbide inserts to shaper steel knives is not good engineering practice. It just won't work.

Tungsten carbide, being a very hard material, is also brittle and therefore the transverse rupture strength is rather low. The deficiency in strength must be compensated for in the application. This is accomplished in two ways, one by reducing the composites, or elements of hardness, to the increment of those promoting greater strength or toughness in the processing of the tungsten carbide. Obviously, this is not desirable since great hardness is what we are after. Another way is to increase strength through the engineering and construction of the knife proper without sacrificing the hard-

ness values. For example, a knife having a tungsten carbide insert one-eighth inch (⅛") in thickness should have the support of one-half inch (½") of steel behind it, or approximately three times the carbide thickness, to increase its strength and thereby withstand the impact of the cut in operation. Tipping shaper steel knives, therefore, does not present a sound application, because the steel section supporting the carbide is not sufficient, since the shaper steel thickness generally used is one-fourth (¼") to three-eighths (⅜") inch.

Incidentally, a disadvantage of shaper steel tipped knives is that resharpening is done on the form or the clearance side of the knife, thereby increasing the maintenance cost as well as the inconsistency of the form. The pressures applied on the shaper steel knives tipped with carbide, when mounted between the collars, promote a movement or flex to the knives, thereby generating stresses to the brazed carbide. This causes cracks, as well as loosening of the brazed bond in many cases.

The ultimate in carbide application for the shaper is a cutter head with removable milled-to-pattern knives, so as to permit use of as many knives as are required and for different shapes. Adequate support for the carbide inserts must be provided in the engineering and design of the head and knives. An example of the type of cutter head I am speaking of will be passed around. You will notice the support that is given the tungsten carbide by a heavy cross section of steel backing. The knives are dovetailed and fitted snugly into their respective openings in the cutter head body. Please take note of the impact and direction angle, which is projected to periphery of the cutter head body, thereby absorbing the shocks or impacts of the cut.

Other features of this cutter head are also relative to sound carbide application. You will see the complete dynamic and static balance obtained, the ease of adjustment of the knives, the positive locking system of the dovetail which makes for complete safety in operation. Incidentally, the safety angle of this cutter head is very important and commendable, since shaper steel knives have taken a toll of so many lives in woodworking plants throughout the country that certain state labor laws prohibit their use.

Applications of tungsten carbide to the moulder and glue jointer are very similar to the shaper. The cutter head again should be of such construction as to accommodate milled-to-pattern removable knives in preference to the blade type. Straight knives for the glue jointer again must be of sufficient strength to withstand the cut, and the principles outlined in the first part of this paper apply. The tenoner machine is a good place to apply carbide. Here we have great peripheral speed, because of the larger cutting circle employed on the tenoner, which is very desirable for tungsten carbide. On all of these applications, tungsten carbide has proven its great resistance to wear, frequently operating for weeks without sharpening, and particularly where working material with glue lines which is so severe on steel knives.

Tungsten carbide knives produce a smooth finish. In many instances, sanding is eliminated entirely. This is due principally to the increase in speed of the cutter head which is available on high frequency spindles. Greater speeds are very desirable for carbides. In fact, speed values of 20,000 to 30,000 spindle R. P. M. would mean production increases of 50 to 60 percent, since the feed factor could then be increased proportionately.

The critical heat range of tungsten carbide is very high, so high in fact that the cutting efficiency of carbide is not affected up to 1500 degrees F. The heat range at which high speed steel will break down at a cutting edge of 55 degrees included angle is between 500 to 700 degrees F. Since the structure of tungsten carbide is not affected by thermal conditions until the critical heat range is approached, we need not be concerned on this point.

The question or rate of feed and spindle speed are very important and should be analyzed on each tungsten carbide application. The wood structure, the moisture content, and the various treatments some of the woods receive prior to shaping are all factors to be taken in consideration; also, before feeds and speed are established for carbide applications. It is generally good practice to increase the cutter head speed whenever possible and, if higher feeds are wanted, the increment should be at a ratio of 50 percent of the increased speed. For example, a 100 percent increase in speed will permit a 50 percent increase in feed. This is

not a fast rule, however, and serves only as a guide. Other factors frequently must be considered. For instance, additional knives used in a cutter head will produce the same result as increasing the spindle speed. For example, by doubling the number of knives in the cutter head, we can increase the feed up to 50 percent. This in turn is also controlled to some degree by the cutting circle available on the machine. Whenever possible, the cutting circle should be increased with the use of tungsten carbide knives.

Let's summarize the attributes of tungsten carbide and evaluate them:

(1) Increased production is possible through greater feeds and speeds.
(2) Down-time on machines for maintenance of knives is decreased.
(3) More uniform and better quality products are produced and in some instances subsequent sanding operations are eliminated.
(4) Certain woods can be used which otherwise could not be worked economically.

Steel knives have served the industry well for many years and will undoubtedly continue to do so. However, it is my belief that tungsten carbide knives will eventually completely replace steel knives on the longer runs, the harder woods, on cross grain cuts, on glue lines, veneers, plywoods and synthetics.

Discussion

Mr. Charles B. Hemming (United States Plywood Corporation): I think there is no question as to the value of tungsten carbide as a cutting edge on tools used in woodworking, particularly where synthetic resin glues lines are also encountered. I would like to ask, however, if such tools can be made to give good service cutting paper. We have an operation which requires the jointing or planing and shaping of the edges of thick packs of kraft paper. We find that good woodworking tools do not perform well for very long and are anxious to know if tungsten carbide would help.

Mr. Corti: We are working on the problem of cutting paper at this time and the results are encouraging. There is the matter of the correct angle of rake which is yet to be determined, after which we believe we will have an answer.

FOREST PRODUCTS RESEARCH SOCIETY

Manufacture of Tight Plywood Cooperage

E. George Stern

Associate Research Professor and Head, Department of Wood Construction, Director, Wood Research Laboratory, Virginia Polytechnic Institute

The mass-production of tight plywood cooperage is described, with particular reference to beer barrels and whisky barrels, the latter of which are also used by bottlers, carbonators, fruit processors, wineries, canners, milk processors, the chemical and many other industries. The advantages of these plywood barrels, as compared with the traditional solid-oak barrels, are summarized. Consideration is given to their uniform capacity, durability, strength, dimensional stability, advantageous wood utilization, speedy fabrication with possible material turn-over from veneer to finished product within four days, suitability for mass-production, easy repair and reconditioning, and possible knock-down shipping and storage. Because of the numerous advantages, the limited production of tight plywood cooperage is expected to expand rapidly and greatly, in order to fill future market needs of industries which to date have not been fully familiarized with the benefits they may derive from the use of tight plywood cooperage.

MANUFACTURERS, packers, and shippers of merchandise are constantly urged to use shipping containers which afford satisfactory protection to the contents, in order to minimize damage during shipping, inconveniences and loss in handling. Availability of proper shipping containers at the right place and time is of utmost importance to enhance their use. To assure such availability, manufacturers and shippers may produce their own shipping containers despite and because of the specialty of such an undertaking. The introduction of mass-production methods for the manufacture of containers is often a necessity in order to achieve economic production. Many new manufacturing procedures for tight plywood containers have been proposed during the last few years. It is the purpose of this paper to make manufacturers, packers, and shippers familiar with mass-production procedures for tight plywood barrels which have been in successful production for several years and have proved their merit during extensive use.

For information on the manufacture of plywood beer barrels, full credit is given to the Camfield Manufacturing Company of Grand Haven, Michigan, molder of staves and heads, and to the Verdi Bros. Cooperage Company of North Bergen, New Jersey, manufacturer of beer barrels. The data on the manufacture of plywood whisky barrels were made available through the courtesy of the General Plywood Corporation of Louisville, Kentucky.

Plywood Beer Barrels

The manufacture of plywood beer barrels[1-3] calls for molding of rough staves and heads, their machining and assembly into barrels, including their treatment and testing. By standardization of these manufacturing steps, the basis of mass-production is ascertained.

The standardized barrel staves and heads are built up of 1/8-in. thick rotary-cut maple and oak-face veneers coated at their contact areas with a 50-percent resin-content Durez phenolic resin. The nine veneers are arranged in such a way that the second and sixth veneers from the outside are cross-veneers in the nine-ply construction. In their final assembly the veneers are laid-up tight for eight hours, during which time the moisture of the glue penetrates the veneers and any excess moisture evaporates. A short time before molding, the face veneers of each set of assembled veneers are moistened to attain optimum molding conditions.

In 150-ton capacity molding presses, twelve barrel staves are molded during a single operation between special smoothly ground cast-steel molds. Each mold consists of a steam-heated chamber with 3/4-in. thick outside walls. Every mold in each of the six daylights of a press forms two staves. As many as eight presses in a row are handled consecutively to produce approximately 200 staves per hour. All molds are provided with spacer stops to allow quick loading of the press by placing the veneer bundle between the side and against the back stops. The molds are also provided with special

stops which ascertain a certain final thickness of the molded stave regardless of the amount of pressure applied. Thus, the full pressure remains applied until the veneers are deformed to such an extent that the pressure stops prevent further closing. Initial pressure is applied slowly, with the pressure of 150 psi. at the initial loading period increased to 750 psi. within approximately one minute. During the following period, until the mold is closed, the veneers increase to deform as a result of the heat treatment, with temperatures reaching almost 300° F. at the constant pressure of 750 psi. The total molding time is 25 minutes. Since the mold is quickly opened, without prior cooling, emptied, and reloaded, a ½-hr. molding cycle can be adhered to.

In similar operations, fourteen square nine-ply beer-barrel heads with eight maple and one oak-face veneers are molded with a single press in one press operation.

Since rotary-cut oak veneers deform appreciably under the molding pressure employed, their thickness is reduced to a little more than $\frac{1}{16}$ inch, while the maple veneers retain almost their original thickness.

A certain amount of springback is provided for. Because of the large amount of pressure applied by the hoops during later assembly and closing of the barrels, the exact amount of springback following molding is of but little importance. The variation in the shape of the molded staves and heads is very small. Any variation is equalized when the individual units are firmly clamped onto the carriages of the shaping and finishing machines. Since molded staves and heads are provided with press marks, their uniform fit onto the carriages of successively operating machines is guaranteed, even if any shape variation should occur during or upon molding.

Upon molding, the rough hot staves and heads are stacked tight, thus retain their heat for a long period. Still hot, they are inspected, any longitudinal molding splits of the face veneers are filled. Such deficiencies are, however, kept to a minimum by proper grading and handling of the veneers and by accurate control of moisture content in the veneers prior to the assembly.

For machining the rough 7½ by 26-in. stave to its final dimensions of $1\frac{3}{32}$ by 6⅝ by 24⅞ in., it is fastened onto a carriage and moved by means of hydraulic pressure between two rotating circular saw blades, set at the proper angle to give the sides of the staves the correct list. Trimming, crozing, howelling, and chiming operations are performed simultaneously for each individual stave or head in special finishing machines. The croze is $\frac{3}{16}$ by $\frac{15}{16}$ in. and has a $\frac{1}{16}$-in. deep howell. A third operation is required for finishing the sides of the staves with two high-speed cutters mounted at the proper angle for the proper list.

Immediately after this operation, the barrel is raised. Since all staves are of uniform size and shape, their assembly is easily and quickly accomplished. The machined closed barrel head is inserted into the loosely assembled staves by means of an air-suction grip. The second head is inserted upon mounting of the end hoop. Finally, all the other electrically welded hoops are driven by means of a special hoop-driving machine.

Upon assembly, each barrel is tested under 50-lb. steam pressure. The barrel ends are machine-sanded. The inner oak-veneer lining is left unfinished by the barrel manufacturer, while the outer oak-veneer lining is sprayed with "Cuprinol," a clear preservative containing copper naphthenate as a toxic ingredient.

This manufacturing procedure allows mass-production of barrels with a content variation of less than one pound. Because of their sturdy veneer and cross-veneer construction, they are extremely strong and show highly satisfactory dimensional stability. Because of this stability, the hoops do not become loose, but remain tight and the uniform capacity is retained. Because of the small number of staves of uniform width,—only nine plywood staves are required as against 16 to 21 in the conventional barrel,—in a single day as many as 300 full or 400 half barrels are produced in a single plant according to the described production principles. While a single cooper can repair five solid-oak barrels per day, he can repair 40 plywood barrels during this period. During such reconditioning of used plywood barrels, still satisfactory old staves are placed next to new ones without distinction, since, because of complete standardization in manufacture, all staves are interchangeable both during manufacture and reconditioning. Because of the interchange-

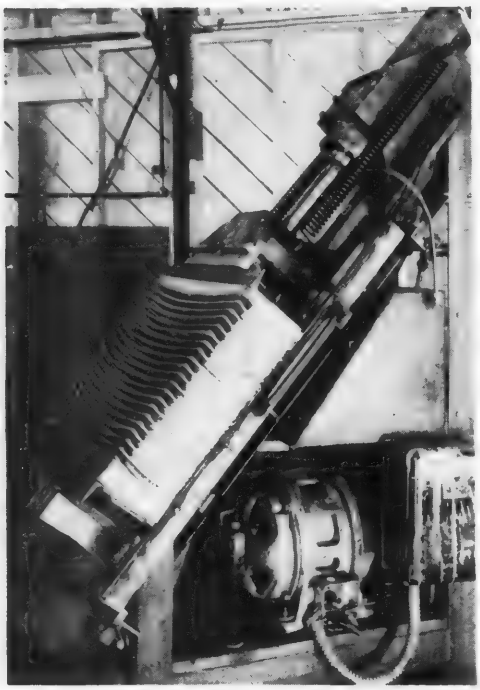


Fig. 1.—Cold-pressing at 200-psi. pressure of four-ply assemblies of resin-coated veneers between formed aluminum cauls for twenty whisky-barrel staves.

ability and dimensional stability of both staves and heads, the barrel may be shipped in knock-down condition and staves, heads, and hoops may be assembled where and when needed, thus, reducing requirements for both shipping and storage space. Other advantages of this type of barrel construction are the rapid turn-out of finished barrels, with veneers possibly cut only four days before shipment of the finished barrel. Also, better utilization of the tree allows the manufacture of twice as many barrels from a given lot of trees than is possible for solid-oak barrels.

Thus, mass-production of tight plywood beer barrels—to date accomplished only by one U. S. company—brings with itself many advantages highly appreciated by the cooperage industry and by those who make use of these modern containers.

Plywood Whisky Barrels

Of somewhat more recent introduction are plywood whisky barrels[4] of 50-gal. capacity, 20 lb. lighter than their solid-oak counterpart. The fourteen standardized and interchangeable staves built up of four rotary-cut kiln-dried white-oak veneers replace the 24 to 30 solid-oak staves of the conventional whisky barrel. The five-ply standardized and interchangeable heads are molded in single square pieces, subsequently rounded and their edges machined. A special phenolic resin was developed for the manufacture of the molded staves and heads. In addition to oak, other species, such as gum, are also successfully used for the manufacture of both staves and heads.

While the manufacturing procedure is similar to that described for plywood beer barrels, it differs insofar as the number of plies is smaller and the molding procedure employed for the staves is different. Four-ply assemblies of resin-coated veneers for as many as 20 staves are simultaneously pressed to proper shape between formed aluminum cauls at 200 psi., as shown in Fig. 1, and bonded during 1½-hr. placement of the cold-pressed packs into a gas-fired oven with electrical temperature and humidity controls, as shown in Fig. 2. In contrast to this procedure, the five-ply heads are molded between steam-heated molds at 250 psi. and 300° F. While the cross-laminated staves for plywood beer barrels are completely finished before assembly, the parallel-laminated

Fig. 2.—Placing of packs of assembled veneers between formed aluminum cauls into gas-fired oven with electrical temperature and humidity controls.

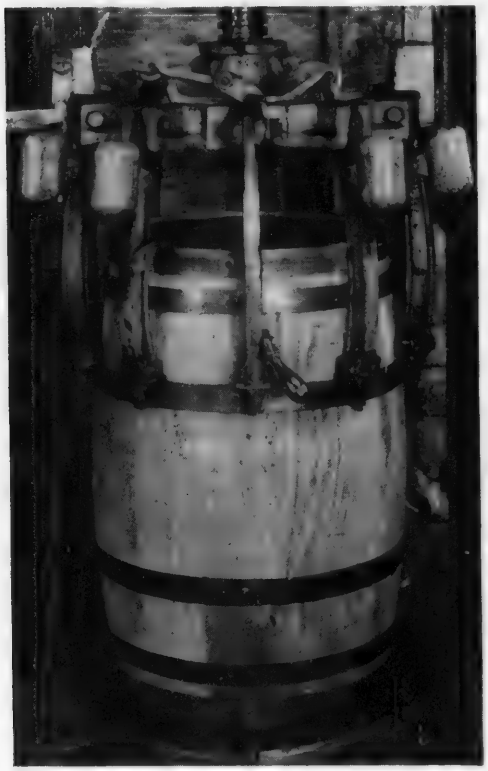


Fig. 3.—Driving of riveted steel hoops onto plywood whisky barrel with standard cooperage hoop-driving machine.

whisky-barrel staves are crozed upon driving of the truss hoop. Whisky barrels are raised with riveted hoops, shown in Fig. 3, and tested for tightness at an air pressure at 10 psi.

These plywood whisky barrels are also used for storage and shipping by chemical industries, by bottlers and carbonators, fruit processors, wineries, canners, milk processors, and others, since these containers fill their special needs better than other means of packing and shipping. Thus, it can be expected that the manufacture of tight plywood cooperage will be greatly expanded and in many cases replace the manufacture of tight solid-oak barrels.

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The Fifth British Empire Forestry Conference

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The Fifth British Empire Forestry Conference, held in London June 16 to July 19, 1947, was attended by about 100 delegates and assistant delegates from 31 British countries. The majority of delegates were officials of their respective governments, usually of the forestry departments; hence the conclusions and recommendations of the conference may have considerable influence upon government action in forestry matters.

Among the approximately 100 papers presented, about 20 related to forest-products research and utilization, of which several were substantial contributions of permanent value.

The Committee on Forest Products Research recommended closer cooperation between those engaged in forest management and protection and those engaged in forest-products research and utilization; the formation of interim committees for interchange of information on forest-products research; and meetings of specialists of the different laboratories to discuss mutual problems in their special fields in greater detail than can be done by policy-making officers.

The Conference recognized that there is a world shortage of timber products as well as an Empire shortage. It recommended continued overcutting as an emergency measure, but pointed out that this must be compensated for subsequently and that the ideal of sustained-yield management must not be abandoned.

THE British Empire Forestry Conference in London June 16 to July 19, 1947 was the fifth in a series of like conferences that began in England in 1920 and have since been held at intervals of several years in different parts of the Empire. The fifth was to have been in India in 1940, but it was delayed by the war until 1947, when it was held in England because of unsettled conditions in India. Other conferences included the second, in 1923 in Canada; the third, in 1928 in Australia and New Zealand; and the fourth, in 1935 in South Africa.

The Conference is made up primarily of delegates from the forestry departments of the various countries of what was formerly called the British Empire, but which is now more appropriately called the British Commonwealth of Nations. There are also a few delegates from timber-trade and timber-control organizations, forest schools, forestry societies, and Departments of Scientific and Industrial Research. The 1947 Conference was attended by more than 100 delegates and assistant delegates from the following countries: Australia; Canada; India; South Africa; New Zealand; Newfoundland; Burma; Eire; Bechuanaland, Basutoland, and Swaziland; British Guiana, Jamaica, and British Honduras; Cyprus and Palestine; Fiji; Gold Coast; Kenya; Malayan Union and Sarawak; Nigeria; North Borneo; Northern Rhodesia and Nyasaland; Southern Rhodesia; Tanganyika; Trinidad; Uganda; Sudan; and Great Britain. In addition, the writer attended the conference by invitation as a guest from the United States and, during part of the time, two representatives of the Forestry Branch of the Food and Agriculture Organization were present by invitation as guests.

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

Official Influence Great

Because the Conference is made up largely of government officials, it has considerable official influence. Its deliberations and decisions are communicated to all the governments concerned and, in the past, have frequently resulted in positive action. For example, the establishment of the British Forest Products Research Laboratory at Princes Risborough followed a resolution of the 1923 Conference recommending that such an institution be established. Similarly, the establishment of the British Imperial Forestry Institute at Oxford followed a 1923 resolution recommending it. Other examples of the strong influence of the Conference can be cited.

No forestry conferences of similar character are held in the United States, nor, so far as I know, anywhere else outside the British Commonwealth of Nations. Our Society of American Foresters, for example, has annual meetings of great importance from the standpoint

of technical progress in all the aspects of forestry and forest utilization, but these meetings have no direct influence upon Government action, even though their indirect influence may and should be appreciable. Similarly, the Forest Products Research Society should in time be able to influence government action in its field by presentation of facts and opinions, but not by any official participation in its deliberations and conclusions. On the other hand, the British Commonwealth of Nations has no forestry organizations of the stature and technological prestige of the Society of American Foresters or the Forest Products Research Society.

One British organization represented at the Conference that offers possibilities of considerable value to American foresters and forest-products research organizations is the Imperial Forestry Bureau, which publishes *Forestry Abstracts,* including a section on forest-products utilization. Those in America interested in what the world's current literature contains on forestry and forest products will find this abstract service of great help. It should be possible to develop cooperative arrangements by which the abstracts can become more generally known and more easily available throughout America. By cooperative effort, also, the coverage of the useful publications in all languages could be made more complete and other worthwhile improvements in the abstracting service be accomplished.

Work of the Conference

The work of the 1947 Conference included five main activities: (1) presentation of prepared papers, (2) committee meetings and discussions on subjects assigned at the beginning of the Conference or subsequently referred to the respective committees, (3) presentation of and debate upon committee reports, with amendments where necessary and final adoption, (4) presentation and discussion of resolutions based upon the committee reports, followed by amendments where necessary and adoption, and (5) visits to forests, institutions, and wood-using plants to see forestry practices and wood utilization in action. It was truly a working conference that seriously applied itself to the job in hand through 28 sessions in 18 days of meetings, in addition to numerous committee meetings and the several field trips.

During the first few days of the Conference, most of the countries represented introduced printed or mimeographed reports on the general theme of "Empire Forests and the War," which gave statistical information on timber production during the war and described the impact of the war upon the forest resources. A summary of all these statistics was then prepared so that the information in condensed form could be available under one cover. There were, in addition, numerous papers describing other aspects of forestry, forestry education, forest utilization, and related subjects. Altogether, about 100 papers were presented, of which about 20 related to forest-products research and utilization. Some of the more important papers were presented orally in brief summaries, but, for the most part, the papers were merely distributed for reading.

The final record of each conference consists of a summary report that gives a brief general description of what was said and done, and that presents in full the committee reports and resolutions as finally adopted. The papers presented at the Conference are not generally republished in the proceedings. The debates or discussions are not usually presented verbatim, although a complete shorthand record is made; they are either summarized very briefly or omitted entirely. Thus, the summary reports of these forestry conferences are more a record of conclusions reached and recommendations made than they are a repository of technical information on forestry and allied subjects. On the other hand, some of the original papers are important publications of lasting value, but of these most have very limited circulation except as they are republished, abstracted, or otherwise made available.

Research and Utilization

Forest-products research and utilization received much greater attention at the 1947 Conference than at any of the earlier meetings. A larger portion of the delegates were interested primarily in the products-research and utilization side of forestry, and a larger number of products-research institutions of the Empire were represented than at any previous

conference. The forest-products research laboratories of Australia, Canada, Great Britain, India, New South Wales, New Zealand, and South Africa were represented by their directors or other high-ranking officials, while many of the other delegates had a strong interest in utilization.

The report of the Committee on Forest Products Research pointed out the importance of close liaison between forestry, forest utilization, and forest-products research. It urged those who grow and protect the forests and those whose chief interest is utilization or products research to have closer acquaintance with and better mutual understanding of each other's problems and accomplishments.

The report also recommended the formation of "corresponding committees," "each under a chairman whose function it shall be to attend to the interchange and collation of information on forest products research. Subjects upon which it is proposed to set up such committees include: Standard Terms and Definitions, Cooperation in Publications, Entomological Problems, Composite Wood, and Preservation." Since these will presumably be Conference subcommittees, their official scope will be limited to British nations and colonies. It was obvious, however, that there is a basic desire to cooperate with other nations in these subjects. Thus the new committees, when they begin to function, can become points of contact and channels for cooperation with committees of the Forest Products Research Society or with forest-products research institutions outside the British Commonwealth of Nations. In the interest of world progress, such cooperation would be highly desirable.

An important fact recognized in the report of the Committee on Forest Products Research was the necessity for meetings of specialists from the various Laboratories for the discussion and interchange of ideas on matters of specialized research. It was pointed out that matters of policy, program, and technology in general can be dealt with by meetings of policy-making officers, but that the details of programs, methods, terminology, and scientific conclusions in specialized fields, such as timber mechanics, chemical or fiber research, wood preservation, pathology, entomology, gluing, seasoning, and others, can only be worked out by the specialists in those fields. The committee recommended, therefore, that such meetings of specialists be held.

The Committee on Forest Products Research called attention to the fact that "Research in forest products has resulted in far-reaching effects in improving manufacturing equipment and processes, in establishing new industries, and in curtailing waste of material. In those laboratories where the program includes a considerable amount of work industrial in character, consideration of economic trends is of great significance." For this reason, the committee recommended that such laboratories should strengthen their staffs by the appointment of officers with special training in economics.

Discussion of this recommendation brought out the fact that some of the forest products research laboratories represented at the Conference were directly connected with the Forest Service of their respective countries. This is true particularly of Canada, New South Wales, and New Zealand. The Australian and British laboratories, however, are under their respective Council or Department of Scientific and Industrial Research and are not officially connected with the forestry service. The latter institutions, therefore, are more free to do basic research of general character and are not required to coordinate their program with that of the forestry service. They seemed to feel less need of economic study in developing their programs than the institutions more directly connected with timber growing and harvesting. All of them, however, seemed to appreciate the need of closer understanding and cooperation between those concerned with timber management and those engaged in forest-products research.

Utilization of Tropical Timber

Another important fact recognized in the report of the Committee on Forest Products Research is the common practice of extracting only the few preferred species when exploiting tropical or subtropical forests. This is a wasteful practice, in that it often results in the use of high-grade woods where secondary species would serve the purpose, it makes for higher logging costs than would be the case if all the available woods were taken at the same time, and it reduces the amount of preferred species

in the remaining stand. Since there are so many secondary tropical species to be considered, the committee recognized that it is now impractical to utilize more than a small proportion of them under their own names. A partial solution would be to "class the secondary species into broad groups or classes, according to their appearance, properties and potential uses, having regard to the fact that the great bulk of timber (as distinct from firewood) is required for purposes such as railway sleepers, house building, flooring, plywood, boxes and crates, joinery and furniture. This concept of grouping of species is not new and has, in fact, operated in this form in Malaya, and in a somewhat modified way in Australia, South Africa, and other countries for some considerable time. . . . The more important factors to be taken into account in assigning a timber to its appropriate utility class are as follows: density, strength properties, appearance, durability and amenability to preservative treatment, working properties and liability to major defects. Comparatively few timbers have been subjected to systematic test and it will be only a small proportion for which the technical data under these heads are reasonably complete and accurate, but a provisional classification of the better known secondaries can be made on the basis of existing knowledge pending their further investigation." The committee recognized that there are serious difficulties to be overcome and that a general or universal scheme of species grouping will not be possible for a long time to come. Such grouping will be most practical in regions that supply definite markets.

Wood Shortage in Empire

Although the point was not made by the committee, the present seems to be a good time for countries supplying England with tropical woods to put such grouping practice into effect. There is a great shortage of timber in England at present, and the English factories making furniture and other wood products can find use for almost any wood they can get. In fact, in one large furniture factory visited, old boxes, crates, skids, and tent stakes left over from the war were being taken apart and, after all metal was laboriously removed, were being worked up into core stock for furniture.In this same plant, miscellaneous war stocks of airplane spruce and Douglas-fir, together with new and old stocks of various other woods from temperate and tropical climates, were being used successfully in the production of "utility furniture." Practically all timber is under close allocation and control. The average allotment of lumber for the "man on the street" is now only 5 bd. ft. per year. The rest is allotted to more important projects and for the manufacture of export articles. Furniture and other plants get only what the timber controller allots them. Naturally, little goes to waste.

The timber shortage is not confined to England. In fact, Canada is the only country of the British Commonwealth of Nations that has a large surplus of timber for export. A few of the tropical countries export also, but not in very large quantities. The general shortage is due in part to lack of logging and milling equipment, shortage of labor, high ocean freights and shortage of ships, and, in some places, to overcutting of available supplies. The Timber Supply Committee reported that the shortage has also been strongly influenced by "considerations of national defense, government policies in different countries, conditions of economic instability and problems of international monetary exchange." This committee further stated that "from information in its possession, gleaned from F. A. O., the British Timber Control, and from Conference statistical data, there exists a large deficit in supply, not only in Empire markets but also in the whole world."

The Conference agreed that continued overcutting is necessary as a temporary expedient, but that it must be compensated for in the long run in the management plans of the respective countries, and that the ultimate goal of sustained-yield management must not be abandoned. The Timber Supply Committee, while recognizing the need for stimulating production, warned against overproduction, and held that "it would be unwise to advocate a stimulation of production beyond a reasonable estimate of absorption capacity."

I will not take the time to comment further upon committee reports or resolutions, except to say that they were carefully thought out, intelligently considered, and generally in accord with the opinions of most foresters with regard to timber management, surveys, utiliza-

tion, research, and forestry education. The Fifth British Empire Forestry Conference was a meeting of outstanding importance to world forestry.

Papers on Forest Products Subjects

Following is a list of papers relating to the field of forest products investigations that were presented at the London Conference in 1947. It is believed to be fairly complete, although some papers may have been inadvertently omitted from the list. To the extent that copies of these papers may be available, they can probably be obtained from the organizations that presented them.

Australia: Forest Products Laboratory, 77 Yarra Bank Road, South Melbourne, SC4.

Anon.: Effect of prolonged loading on the strength and elastic modulus of timber. 6 pp. processed.

——: Effect of temperature on the strength and elastic modulus of timber. 5 pp. processed.

Canada: Forest Products Laboratory, Ottawa.

McElhanney, T. A.: Conservation by better utilization. 24 pp.

——: Forest products research in Canada. 15 pp.

Ceylon: Ceylon Government Press, Colombo.

Holmes, C. H.: Prevention and or control of insect borers and fungal stains and decay on malaboda (*Myristica dactyloides* Gaertn.)

England: The Forest Products Research Laboratories, Princes Risborough, Bucks.

Anon.: The Forest Products Research Laboratories. 13 pp.

——: Research in relation to timber-using industries. 4 pp. illus.

Cox, H. A.: Modern trends in timber utilization. 4 pp.

Fisher, Ronald C.: Some timber insect problems in utilization in the tropics. 5 pp.

Knight, R. A. G.: Notes on adhesive testing. 4 pp. processed.

Lacey, P. M. C.: Application of radio frequency methods to glue setting. 3 pp. processed.

Rendle, B. J.: Cooperative research in the development of the Empire's timber resources; and a project for a survey of the timbers of tropical Africa. 7 pp.

India: Forest Research Institute, Dehra Dun.

Bhargava, M.: Review of the pulp and paper industry in India. 6 pp.

Krishna, S., and R. L. Badhwar: Exploitation of minor forest products. 6 pp.

Stewart, D.: Short review of current research work on forest products. 9 pp.

Malaya: Malayan Forest Service, Kuala Lumpur.

Edwards, J. P.: Malayan timbers for export. 4 pp.

New Zealand: State Forest Service, Box 1, Government Buildings, Wellington. C1.

Entrican, A. R.: Program of work, New Zealand Forest Service, Branch of Forest Products. 50 pp.

Ward, W. C. and J. W. Syme: Adaptation of Scandinavian sawing practices to the conversion of exotic softwoods in New Zealand. 7 pp.

South Africa: Forest Products Institute, P. O. Box 727, Pretoria.

Krogh, P. M. D.: Comparative efficacy of preservatives in wood exposed to termites. 11 pp. illus.

Scott, M. H.: Short review of work in progress at the Forest Products Institute. 5 pp. processed.

Scott, M. H. and R. P. Stephens: Quality of mature *Pinus patula* and *P. insignis* timber grown in South Africa. 23 pp. illus.

Turnbull, John M.: Some factors affecting wood density in pine stems. 22 pp.

United States: Forest Products Laboratory, Madison, Wis.

Hunt, George M.: Forest products research in the United States in war and in peace. 6 pp. processed.

——: The future of wood as a raw material. (Wood, (Chicago) September 1947).

The History and Activities of the Wood Forum

Charles G. Tickle

Editor, "Timber and Plywood," London, England, and Hon. Secretary of The Wood Forum

ALMOST a year ago a small group consisting of half a dozen specialists in different branches of wood technology, a botanist, a forester, and a timber journalist met in London to explore the possibilities of forming a broadly based society for those interested in wood as a material.

Among those whose professional and industrial interests are centered in the study and use of wood, the lack of facilities for discussion and social contact had been keenly felt for some time. When the group came together, there was in fact no non-institutional center where technically minded folk could foregather to clarify their own ideas, and learn something of the work of their fellows in laboratory and factory and thus remove the sense of isolation which so often goes with specialization. It was realized that under modern conditions proper wood utilization calls for teamwork between industrialist and scientist, and the group thought such teamwork could not be achieved by formal relations alone but must also grow out of friendly discussion between individuals and among groups.

Initial Organization

After one or two preliminary meetings, the group—at this stage simply a handful of friends whose paths had crossed at some point in the course of work or study—decided to constitute themselves a provisional committee which would arrange a series of monthly meetings during the winter of 1946. No hard and fast constitution was drawn up and it was decided that for the initial series of meetings, at least, a completely informal, round-table form of discussion should be the aim. It was agreed that the cardinal need was a forum for frank and maybe hard-hitting discussion—the kind of interchange of viewpoint which is rarely possible in large, highly organized gatherings —and that small vigorous meetings, with everyone helping to thresh out a problem, would be more valuable than full-dress lectures, followed by desultory questions and skimped discussion.

The first open meeting took place on October 2, 1946, when the subject "Timber Grading and Stress Grades" provided scope for an extremely useful exchange of views between engineers, wood technologists and a number of commercial timbermen who had been invited to attend.

At a business meeting held after the technical discussion, a number of decisions were taken. These represent virtually all the constitution the society has acquired to date. It was decided (1) that the new society should be called The Wood Forum; (2) that membership should be open to everyone interested in wood utilization in its broadest sense; (3) that meetings should be held on the first Thursday in each month, preferably after an evening meal taken in company; and (5) that a different Chairman should preside at each meeting.

The Committee

The founders committee, with several additions, was re-elected at a general meeting in January 1947 and now consists of the following:

R. G. Bateson, B. A. (Scientific Staff, Ministry of Works — formerly Officer-in-Charge, Seasoning Section, F. P. R. L.)

S. H. Clarke, M. Sc. (Director of the Fire Research Dept., D. S. I. R.—formerly attached to the Wood Structure Section, F. P. R. L.)

H. E. Desch, B. Sc., D. Phil., F. R. I. C. S. (Consultant in wood technics)

G. V. Donnelly (London Manager and Technical Adviser, Travis & Arnold, timber distributors)

F. W. Jane, Ph. D., D. Sc., F. L. S. (Lecturer in botany and wood anatomy in the University of London)

E. H. Pinto (Managing Director, Compactum, Lt.—manufacturing interest)

T. J. Price (Director, George E. Gray, Ltd., timber distributors)

P. O. Reece, A. M. I. C. E., M. I. Struct. E., A. M. Inst. C. E., M. Cy. E. (Director of Constructional Research, Timber Development Association)

T. B. Sillars (Managing Director, Timber Fireproofing Company)

C. Sisley (Jenson & Nicholson, Ltd.—wood preservation interest)

C. G. Tickle (Editor, "Timber & Plywood" —*Hon. Secretary of Forum*)

S. E. Wilson, M. Sc., Ph. D., D. I. C. (Wood products consultant — *Chairman, Wood Forum Committee,* and incidentally, the member on whose initiative the first steps toward the creation of the Forum were taken)

R. P. Woods, B. A. (For) (Technical Officer, Timber Development Association)

It should be noted that the members of the committee, as indeed all members of the Wood Forum, have joined the Society in a personal capacity and do not represent the organizations or firms with which they may be associated. Professional affiliations are shown here merely to illustrate the broad cross section of interests embraced by the Wood Forum.

It is known that members of the staff of the Forest Products Research Laboratory at Princes Risborough are interested in the activities of the Wood Forum, but cannot attend meetings since Risborough lies some way from Town. The fact that Lab. personalities are not attached to the committee must be explained by physical rather than spiritual separation!

Winter Program 1946–47

Altogether nine discussion meetings were held during the winter of 1946 and spring of 1947. The Forum has not met during the holiday months, July to September, but reassembles for the new series of discussions on October 9th.

Evenings have been devoted to discussions on the subjects of Stress Grading; Forestry Problems and the Wood User; Wood and Its Rivals (two evenings); Synthetic Resins as Adhesives; Modern Veneering Methods; and The *Lyctus* Problem Today. Two further evenings were devoted to general discussion of current technical problems of wood use.

After the first few meetings, discussions have followed an evening meal at Schmidt's Restaurant in Charlotte Street, which borders on London's Soho district.

Development

Membership has grown rapidly and there are today just under 60 members, representing practically every branch of activity connected with the study and processing of wood and its derivatives. Allied sections, such as the glue technologists, are strongly represented, as are designers in wood and the various branches of the timber industry. Intercourse between wood user and wood distributor has been cited as one of the most useful features of the Forum.

Growth has brought its own problems: How best can the social atmosphere and informality of our meetings be preserved in face of larger and larger gatherings? Attendance averages about 35, but on occasion meetings are even bigger. Our experience has been that, whereas a first-rate discussion can occur with about 30 members present, the addition of another dozen or so restricts discussion and contributions tend to be concentrated in a few hands. One solution would be to split up into smaller groups, but it is thought that this might lead to the subject-segregation we are anxious to avoid. No one, however, is very worried about such growing pains and no doubt we will work through to a solution during the coming session. Everyone is agreed that the Wood Forum has quite a future and the form later activities will take and the organization needed to carry them through are things which we cannot foresee at the moment. The main thing is that the society is young, vigorous and full of people with ideas.

Publications

At the moment the Wood Forum does not record its "transactions." Nor does it publish literature of its own.

Publicity does not need canvassing and fairly full reports of discussions appear in the four timber journals, whose editors are members of the Forum on the same basis as everyone else. The journals represented are "Timber News" (monthly), "Timber & Plywood" (weekly), "Timber Trades Journal" (weekly), and "Wood" (monthly).

BUSINESS MEETING

President Gottschalk called the business meeting to order at 11:00 a. m. on Saturday. He reported on the following:

a. Total membership of 955 at this date.

b. Meeting attendance reached 478.

c. Plans to bind and distribute Proceedings of these sessions provided sufficient advertising can be obtained.

d. A membership drive to obtain members by means of applications and reply cards enclosed with the directory, which was mailed to all members.

e. The next annual meeting, at which officers will be elected, is scheduled for late March; the exact date to be determined later.

f. General status of Society headquarters in Madison.

A word of appreciation to the authors of papers and those who joined in the floor discussion was extended by Vice-President Garratt. Those who had suggestions for the next meeting, or who had papers to offer, were asked to forward these at an early date.

Reports from the several committee chairmen were then received.

Abstracting Committee

The Committee consists of:

Gustavus J. Esselen
J. Elton Lodewick
Alexis J. Panshin
S. G. Smith
Charles B. Hemming, *Chairman*

Mr. R. B. Taylor has also been asked to serve, but because of illness has so far been unable to do so.

The Abstracting Committee wishes publicly to express appreciation to those who have helped immensely with valuable suggestions.

This committee has been charged with the responsibility of developing and recommending an abstracting program to the Society. Because of the importance of abstracts to the members, we feel that our charge is a heavy responsibility. However, the unanimity of opinion particularly on what might be called the five cardinal points gives us a considerable measure of confidence. I will list these five points. They are:

1. That we do not purchase British Forestry abstracts.
2. That we develop our own service and style.
3. That we start on a small but well organized scale and do only that amount of abstracting within our ability but do it well.
4. That we use volunteer member abstractors.
5. That a full-time paid individual, possibly the Secretary, be employed so that he can handle the all important job of editing and handling the abstracts and managing the abstractors.

There are ten other recommendations on which I do not wish to report at this time except to describe briefly two proposed methods for getting the abstracts to the membership. One of these is to publish them in the Society's Monthly Bulletin in *Wood*, but there is a problem to be overcome in this case which, however, is not without precedent and, therefore, may well be solved. The other is to planograph the abstracts on an 8½ by 11 inch page, four abstracts to the page which will be sent to the members who will cut the pages into quarters and file them chronologically or by subject as he prefers.

The choice of method and final recommendations on the other ten points, it is expected, will be completed shortly.

Publications Committee

The Committee consists of:

E. A. Behr
John B. Grantham
Frederick H. Vogel
Frank H. Kaufert, *Chairman*

The Publications Committee has completed a preliminary draft of a style manual for the Forest Products Research Society. This preliminary style manual has been circulated to some members of the Society and many of the suggestions made have been incorporated by the Committee. In preparing this style manual, the Committee does not intend to interfere with individual writing styles or presentations. The manual is sufficiently general so that there is little danger of this occurring. The principal objective of the style manual is to bring about uniformity in details of manuscript preparation and thus make the job of editing simpler and facilitate publication. In the style manual the Committee has purposely avoided certain issues which we recognize must be faced in the future. One of these specific problems is whether we should adopt the common names proposed in the new Check List. For the time being, it was decided that we should continue to use the common names in general use but the possibility of adopting the Check List recommendations will be considered for future changes.

It is the understanding of the Publications Committee that the style manual will be published in the Proceedings of the Forest Products Research Society; and we will welcome comments and suggestions for improvements and changes from all members. Since the style manual is not in its final form, desirable changes can be incorporated.

The Committee expects to aid in the editing of papers presented at this meeting before publication in the proposed Proceedings and in carrying out such duties relating to publication as the Executive Committee may assign us.

Chicago Meeting Committee

The Committee consists of:

E. A. Behr
Charles E. Close
William C. Finley
Charles H. White, *Chairman*

Chairman Charles H. White reported that income from banquet, table-top exhibits, etc. was approximately $1,200 and the expenses will be about $1,100 to $1,200. Arrangements for packing and the collect shipment of a number of large exhibits will be handled by the Committee for exhibitors without extra charge on Monday.

Secretary-Treasurer's Report

Secretary-Treasurer T. R. C. Wilson reported that due to the membership added during the meeting that an exact accounting was not possible, but that the bank balance of the Society was about $3,500. This, it was pointed out, was an excellent financial situation for the new Society.

Business From the Floor

Professor L. A. Patronsky of the University of Michigan suggested that consideration be given to the formation of student branches of the Society at various forestry schools. Mr. R. A. Hertzler inquired about sectional organization. Messrs. J. H. Gividen, J. S. Horner and others commented about the service the Society had provided.

Prize Award

President Gottschalk reported that Mr. H. A. Vance, publisher of *Wood,* had established an annual award of five hundred dollars together with a plaque of recognition for the best forest products thesis submitted by a student in an American college.

Adjournment

After announcing the incorporation of the Society as a not-for-profit group under the laws of the State of Illinois, the president adjourned the first national meeting at noon, November 1.

TABLE-TOP EXHIBITS

Displays were set up in the Exhibit Room, adjacent to the Furniture Club, by producers of forest products, suppliers of equipment, or material used by the forest products industries, consumers of wood, laboratories in the wood field, etc. These were open for the entire period of the meeting. The purpose of the table-top display is to provide information for those concerned with forest products development, production or utilization. The facilities for the space was made available through the courtesy of Colonel Lawrence H. Whiting, President, and Mr. Frank S. Whiting, Vice-President, of the American Furniture Mart. The exhibitors were:

American Lumber & Treating Co.
Battelle Memorial Institute
Leonard J. Buck, Incorporated
Caribbean Plywood & Plastics Corp.
Casein Company of America
Cocker Saw Co. Inc.
Henry Disston & Sons, Inc.
The Dow Chemical Company
Elmendorf Corporation
Fenlind Engineering Company
Forman, Ford and Company
B. F. Goodrich Chemical Company
Hart Moisture Gauges, Inc.
Haskelite Manufacturing Corp.
Holgate Brothers Company
Hyster Company
Mall Tool Company
Marcoloy, Inc.
Masonite Corporation
Monsanto Chemical Company
Northeastern Wood Utiliz. Council
Perkins Glue Company
Pluswood, Incorporated
Porto Pump Incorporated
Rilco Laminated Products, Inc.
Risser Dry Kiln Engineers, Inc.
Walter E. Selck and Co.
Spotnails, Inc.
Standard Dry Kiln Company
Taylor–Colquitt Co.
Timber Engineering Company
U. S. Forest Products Laboratory
Bureau of Agricultural & Industrial Chemistry
A. F. Vyse & Co.
University of Washington
Westinghouse Electric Corporation
Wood
Wood Conversion Company
Woodwelding, Inc.
Wood Working Digest

Attendance List

First National Meeting

CHICAGO, ILLINOIS
OCTOBER 31–NOVEMBER 1

NORTHEAST REGION

CONNECTICUT

New Haven
John T. Blackwell, Northeastern Wood Utilization Council
George A. Garratt, Yale University

Springdale
M. A. Corti, Marcoloy, Inc.
John A. Horton, Marcoloy, Inc.
Margaret McCormick, Marcoloy, Inc.
Robert S. Minor, Marcoloy, Inc.

MASSACHUSETTS

Cambridge
Albert G. H. Dietz, Massachusetts Institute of Technology

Newton
Paul D. Zottu, Consulting Engineer

NEW HAMPSHIRE

Durham
Lauren E. Seeley, University of New Hampshire

Laconia
Joseph Kepes, Allen-Rogers Corporation

Manchester
Paul H. Graham, Woodworking Consultant

NEW JERSEY

Arlington
B. C. Bren, E. I. duPont de Nemours & Co.

Fords
Wesley R. Thompson, Catalin Corporation

Jersey City
C. A. Klebsattel, Advance Solvents and Chemical Corporation

Ridgewood
W. Burdette Wilkins, Consulting Engineer

Rockaway
Earl R. Stivers, Package Research Laboratory

NEW YORK

Bainbridge
George B. Fahlstrom, Casein Co. of America, Div. of The Borden Co.

Cattaraugus
C. E. Van Epps, Setter Bros., Inc.

Lockport
Glen P. Harris, Monsanto Chemical Co.
Alan A. Marra, Monsanto Chemical Co.
F. Somers Oldham, Cocker Saw Co., Inc.

New Rochelle
Charles B. Hemming, U. S. Plywood Corporation

New York City
Nils Anderson, Casein Co. of America, Div. of The Borden Co.
B. A. Anderton, The Barrett Division, Allied Chemical & Dye Corporation
N. Contino, L. J. Buck, Inc.
A. M. Freeman, Casein Co. of America, Div. of The Borden Co.
Thomas H. Friedlin, New York Central System
Robert L. Hiller, American Cyanamid Corporation
Alexander Lobert, Hart Moisture Gauges, Inc.
Paul H. McCormack, National Adhesives
D. A. Mitchell, The Barrett Div., Allied Chemical & Dye Corp.
V. C. Otley, The Barrett Div., Allied Chemical & Dye Corp.
Thomas J. Reese, Boliden Mining Co. of Sweden
Joseph L. Rodgers, Bakelite Corporation
L. B. Shipley, Bernuth, Lembcke Co., Inc.
Harry Hull St. Clair, Hart Moisture Gauges, Inc.

ONTARIO

Ottawa
T. A. McElhanney, Forest Products Laboratories of Canada

PENNSYLVANIA

Kane
George Perlin, Holgate Bros. Company

Lansdale
James F. Hamilton, Perkins Glue Co.
Philip A. Macy, Perkins Glue Co.

Petrolia
R. C. Rinker, Koppers Co., Inc.

Philadelphia
P. D. Brentlinger, Pennsylvania Railroad
Ralph T. Breyer, F. W. Tunnell & Co.
Roy M. Carter, U. S. Forest Service
R. C. Fraunberger, S. E. Industries, Inc.
W. H. Fulweiler, Chemical Engineer
Arthur L. Smith, Resinous Products & Chemicals Co.

Pittsburgh
Caleb Davies, Jr., Disco Co.
James N. Roche, Koppers Co., Inc.
Gilbert Thiessen, Koppers Co., Inc.
George A. Wagner, Koppers Co., Inc.

Sewickley
Clarence W. Farrier, Gunnison Homes, Inc.

State College
Newall A. Norton, Pennsylvania State College

QUEBEC

Kenogami
Harold S. Hill, Price Bros. & Co., Ltd.

Montreal
Loren L. Brown, Dominion Tar & Chemical Co., Ltd.
A. Koroleff, Pulp & Paper Research Institute of Canada

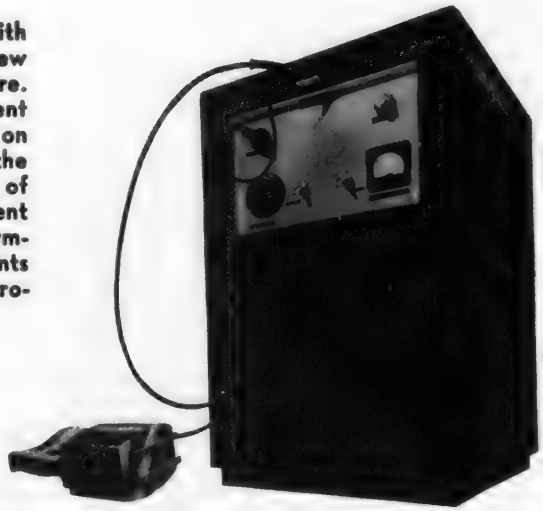
the name that's

OFFICIAL

with America

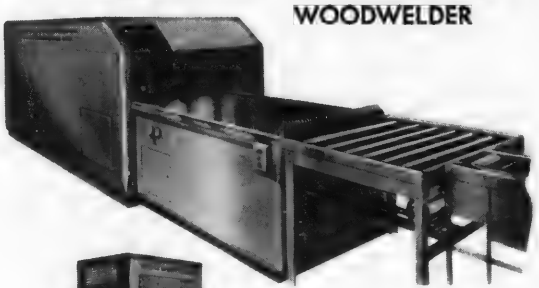
LOOK FOR IT
ON ALL SPORTS
EQUIPMENT

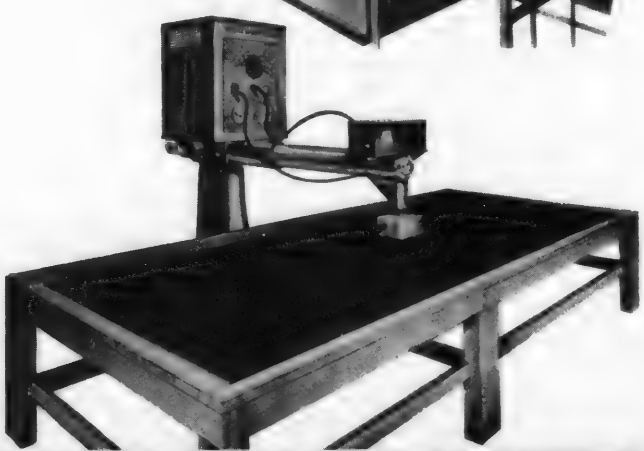
WOODWELDING, INC., announces with pleasure the development of the three new high-frequency instruments pictured here. Designed for three entirely different types of operation—although based on one sound high-frequency principle—the three products are excellent examples of the wide versatility achieved in recent years by Woodwelding, and clearly symbolic of the even newer accomplishments that can be expected by the wood products industry in the near future.



WOODWELDER

FLUSH DOOR WELDER





PANEL PATCHER

Woodwelding, Inc.

3000 WEST OLIVE AVENUE, BURBANK, CALIFORNIA

WOODWELDER
FLUSH DOOR WELDER
PANEL PATCHER

The new, improved Woodwelder model is engineered to meet fixed frequencies as allocated by Federal Communication Docket No. 7858, Section 18.21 governing high-frequency Woodwelding equipment. The new model is powered by two carbon-plate oscillating tubes, with a 1 KW output capacity capable of supplying 3500 BTU's. This Woodwelder has even greater range than previous Woodwelder models, taking care of a wider variation of applications in a multitude of wood products fields. The newly-designed hand-gun has advanced improvements giving greater efficiency and production in rapid-fire "spot-welding", and also on continuous welding on the glue line.

The new Flush Door Welder, now offered to high-production shops, is seen in the act of staggering and edge-gluing scrap into a solid core that will be put into a drum sander and then returned to the same press for cross-band and face veneer, thus resulting in the manufacture of a finished flush door. Dimension-stock mills as well as box plants, furniture factories and countless other wood products manufacturers waste millions of feet of kiln-dried stock every year that has a monetary value equal to the cost per board foot of the original stock from which it came. The Door Welder represents high-speed fabricating equipment that has been in great need for many years for the salvage and utilization of random widths and lengths of kiln-dried stock.

The new Panelpatcher by Woodwelding is designed to speed up the repair of plywood panels with normal defects requiring a boat-shaped patch. The unit consists of a hardened mycalex patching head with electrodes embedded on the under side, a high-frequency 1 KW Woodwelder generator supplying the power, a special Tuning Unit to regulate the amount of power needed, and the specially-designed revolving pedestal and arm combination completing the Panelpatcher. In operation, the electrodes press down on the patch being welded on the panel under a maximum force of 300 pounds per square inch supplied by an air cylinder. Only five seconds are required to "cure" a patch.

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MONTHLY BULLETIN—MAY 1947*

Objects and Purposes

The objects and purposes of this Society shall be (1) to facilitate the interchange of information among individuals and organizations who are interested in forest products research, development, or utilization (a) by abstracting papers, reports, and other publications, (b) by publishing and distributing pertinent information, (c) by encouraging cooperation among interested persons, (d) by promoting standard test methods and procedures, (e) by sponsoring meetings for the presentation and discussion of reports of investigations and experiences of its members and others, for the interchange of ideas, and for the broadening of acquaintanceships among individuals interested in forest products research, development, or utilization; and (2) in general, to encourage and promote the efficient utilization of wood and other forest products.

The Society shall be operated on a nonprofit basis.

History of Founding

For many years various leaders in the field of forest products development have discussed the need of such an organization; definite plans were made during a nation-wide conference on state and federal wood research in March of 1946. The groundwork was laid for this permanent organization by a motion at that time by S. T. Dana, Dean of the University of Michigan School of Forestry and Conservation, empowering an organizational committee to proceed. Action was taken to include representatives of industry on the committee.

After several months, an active organizational committee was established as follows:

Chairman, Bror L. Grondal, Professor of Forestry, University of Washington.

Nils Anderson, Vice-President, Casein Company of America.

William J. Baker, Technologist, Forest Products Laboratory.

Kenneth G. Chesley, Director of Research, Crossett Lumber Co.

Robert A. Cockrell, Associate Professor of Forestry, University of California.

Harold S. Crosby, Forest Products Engineer, Northern Hemlock and Hardwood Association.

Stanley Fontanna, Michigan Planning Commission.

George A. Garratt, Dean, School of Forestry, Yale University.

Fred W. Gottschalk, Technical Director, American Lumber & Treating Co.

James F. Hamilton, Technical Service Director, Perkins Glue Co.

R. N. Hammond, Research Laboratory, Pulp Division, Weyerhaeuser Timber Co.

Ralph W. Hayes, Professor of Forestry, Louisiana State University.

C. B. Hemming, Chief Chemist, U. S. Plywood Corporation.

George M. Hunt, Director, Forest Products Laboratory.

Edward G. Locke, Chemical Engineer, U. S. Forest Service.

Broder F. Lucas, Professor of Forestry, University of Arkansas.

Gordon D. Marckworth, Dean, College of Forestry, University of Washington.

L. J. Markwardt, Assistant Director, Forest Products Laboratory.

H. S. Newins, Head, School of Forestry, University of Florida.

P. B. Proctor, Head, Wood Products Department, School of Forestry, Oregon State College.

Carl A. Rishell, Director of Research, National Lumber Manufacturers Association.

W. H. Swanson, Chief of Staff, Kimberly-Clark Corporation.

Jac. H. Tigelaar, Director of Research and Tests, Haskelite Manufacturing Corporation.

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Others were invited to join in the formative work, but due to previous plans, travel difficulties, or other factors, they could not actively participate.

Organizational Committee Meets

On January 3, Chairman Grondal called a meeting which was attended by the chairman, Baker, Chesley, Crosby, Garratt, Gottschalk, Hamilton, Hammond, Hemming, Hunt, Marckworth, Markwardt, Swanson and Tigelaar. The committee was enthusiastic about the founding of an organization open to all persons interested in forest products research, development, production or utilization. Considerable discussion covered the need for a group to cut across all existing professional societies in order that the forest products fields be more adequately served by an interchange of information and the promotion of more efficient utilization methods. Getting basic information to those who manufacture or use wood appeared to be a primary need. Membership was purposely opened to anybody interested in forest products —technicians, research workers, shop foremen, mill superintendents, and administrative executives.

After the adoption of Articles of Association and By-laws, officers were elected. Since the By-laws set the term of office of a Regional Executive Board member at three years, with two to be elected each year, six Regional members were elected, and lots were then drawn to determine the terms of the initial Regional members of the Executive Board. The new Executive Board appointed William J. Baker to serve as Secretary-Treasurer until March 31, 1948, since this is not an elective position. Inasmuch as there was no past-president, Bror L. Grondal was elected to serve in the office of past-president. Elected officers of the Forest Products Research Society, with the exception of the secretary-treasurer, were as follows:

Fred W. Gottschalk, President.

George A. Garratt, Vice-President.

Bror L. Grondal, Past Chairman

William J. Baker, Secretary-Treasurer

Edward G. Locke, Northwest Region, (to serve one year)

Jac. H. Tigelaar, North-Central Region (to serve two years)

Robert A. Cockrell, Southwest Region (to serve two years)

Carl A. Rishell, Southeast Region (to serve three years)

Kenneth G. Chesley, South-Central Region (to serve three years)

The Society, while national in scope, will comprise six regions. These regions, in turn, will be composed of sections, of 10 or more members residing in the same area. The six regions designated are as follows:

Northeast

Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont, and adjacent Canada.

Southeast

Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, and West Virginia.

From: Left to Right—Carl A. Rishell, James F. Hamilton, Bror L. Grondal, George A. Garratt, Fred W. Gottschalk, William J. Baker, Robert A. Cockrell, Edward G. Locke, Jac. H. Tigelaar.

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North Central

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South Central

Alabama, Arkansas, Kansas, Kentucky, Louisiana, Mississippi, Missouri, Oklahoma, Tennessee, and Texas.

Northwest

Alaska, Idaho, Montana, Oregon, Washington, and adjacent Canada.

Southwest

Arizona, California, Colorado, Nevada, New Mexico, Utah and Wyoming.

For the time being membership is limited to residents of the United States (and its possessions) and Canada. Charter membership is open until September 30, 1947, as follows:

Voting Member shall be any individual who is actively engaged in research, development, production, or utilization of forest products.

Associate Member shall be any individual who is interested, but not actively engaged in research, development, production, or utilization of forest products.

Supporting Member shall be any organization or individual who financially assists the Society through the payment of larger dues.

According to the By-laws the fiscal year shall begin on April 1 and shall terminate on March 31 of each year. The annual dues, payable during the first two months of the fiscal year, shall be as follows: Voting Members, $10.00; Associate Members, $10.00; and Supporting Members, $100.00.

Application forms for prospective members are available from the Secretary-Treasurer.

Sections of the Society may be authorized by the Executive Board upon written petition of ten (10) or more Voting Members residing in a geographic area small enough to justify the belief that an effective local organization may be established. Section members shall be members of the Society. A Section must hold at least one meeting each year in order to retain its authorization.

First Executive Board Meeting

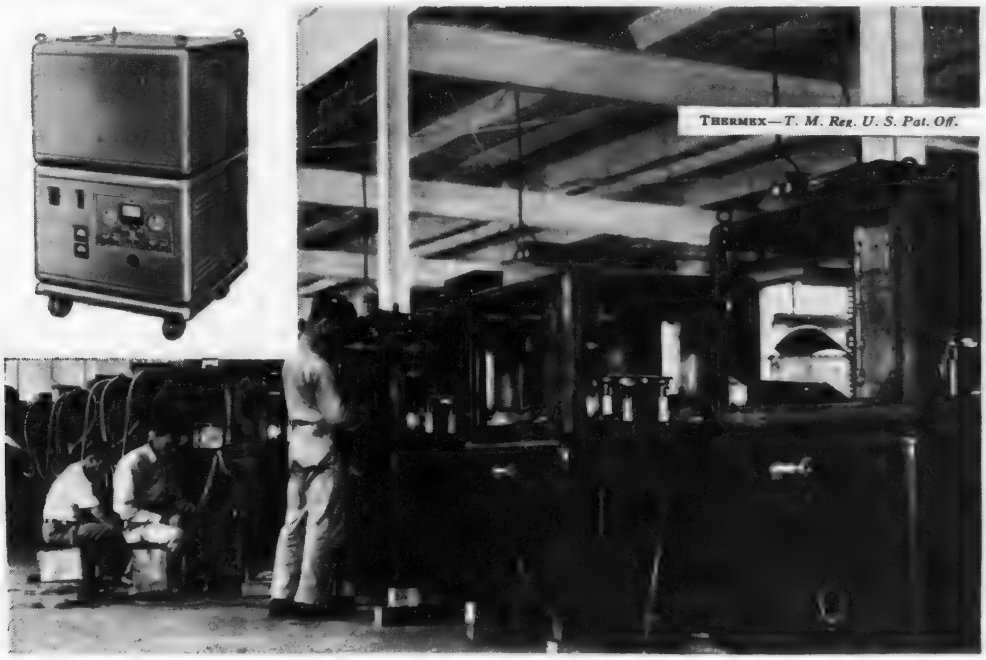
On April 7, in Chicago, the Executive Board held its first meeting since organization in January. Action was taken to hold a general meeting of the Society in Chicago during the latter part of October of this year and the first regular annual meeting in March of 1948. At these meetings a great number of papers will be presented and attendance is open to anybody concerned with forest products. Plans were drawn up for abstracting various forest products publications and the establishment of Society sections.

The Society will be of special interest to the non-technical man who is dealing with various forest products because it is devoted to bringing together new information on theory and practice in the fields of:

Adhesives, Aircraft, Bark Products, Boat and Shipbuilding, Boxes and Crating, Carbuilding, Charcoal, Chemicals, Construction, Containers, Cooperage, Crossties, Equipment, Fabrication, Fiber Board, Flooring, Furniture and Fixtures, Laboratories, Laminated Wood, Logging, Millwork, Mine Timbers, Naval Stores, Piling and Posts, Poles and Crossarms, Pulp and Paper, Plywood, Preservation, Remanufacture, Sawmilling, Seasoning, Shingles and Lath, Tannins and Dyes, Vehicles, Veneer, Venetian Blinds, Waste Conversion, Wood Finishes and Paints, Wood-Base Plastics, Woodenware and Novelties, and Wood Turning.

Monthly Information Service

By arrangement with the publishers of WOOD magazine, the Forest Products Research Society will for the present have this monthly report in this journal as a means of communicating with and giving service to its members and to the entire wood-using public.



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The Executive Board of the Society and the publishers of WOOD have agreed that this arrangement will continue for 12 months and for as much longer as proves mutually agreeable and beneficial, and they are following publication procedures of similar nature as established by other societies and associations.

It is not intended to use these pages for the publication of original technical articles; these will continue to be published, as at present, through the established trade and scientific press. The intention is rather to use the limited space available to the Society for FPRS news, references to or abstracts of important articles on forest products research and development published elsewhere, summaries of progress in research indifferent fields, descriptions of the research institutions of the world, editorial comment, and other items of interest to members.

As a part of the agreement, all members of the Society will receive WOOD magazine as one of the benefits of their membership.

Society Progress

An active campaign has been started, with the excellent cooperation of the wood-industry press, to build up the membership of the Society. A large and active membership and a sound financial position are the first requirements in the life of the Society. The extent to which it can be of service will be influenced greatly by the successful attainment of these objectives. Until it becomes financially strong, the business of the Society must be carried on by volunteer service from its officers, particularly the President and Secretary, and by part-time stenographic and clerical help. As the membership increases the burden upon the Secretary will increase beyond the point where it can be handled on a volunteer basis. The stenographic and clerical work will also increase soon to the point where a full time paid employee will be required. The first business efforts of the Society officers, therefore, are being directed to making the Society self supporting through a large membership.

The By-laws of the Society provide for supporting membership at $100 per year. It is hoped that a substantial number of these can be obtained at an early date because of their importance to the financial strength of the organization. When the wood industries begin to appreciate the value of the Society in speeding up and facilitating the application of research to industrial development and utilization progress, their assistance in the form of supporting memberships is to be expected.

At this date there are over three-hundred members in the Society, including a number of Supporting memberships.

Forest Products Laboratories of the World

Since the establishment of the U. S. Forest Products Laboratory at Madison, Wisconsin in 1910, as a branch of the Forest Service of the U. S. Department of Agriculture, the need for research and development in forest products utilization has been recognized in many countries. As a result, nearly a score have set up organizations and laboratories of their own that are now adding significantly to the fundamental knowledge about wood and its behavior as well as studying problems that apply specifically to their own countires. Any attempt at a complete list is unlikely to succeed, but it is known that there are government laboratories for research in forest products in at least the following countries: Australia, Brazil, Canada, China, Czechoslovakia, England, Federated Malay States, Finland, France, Holland, India, Russia, Sweden, Norway, Union of South Africa, and the United States. Undoubtedly, forest products research is being done in other countries even though they may not yet have established a formalized forest products laboratory.

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MONTHLY BULLETIN—JUNE 1947*

Membership Analysis

An analysis at this time of the membership of the Forest Products Research Society seems appropriate in order to answer many of the questions that are raised regarding Society membership. Of the nearly 400 Charter Members, 99.5 per cent are men representing a great variety of enterprises and occupations; 0.5 per cent of the membership is represented by women research workers. For convenient reference and to conserve space, the analysis is presented in tabular form.

Membership Percentages by Types of Business

Research establishments	18.8
Logging, lumber manufacture and distribution	13.2
Pulp, paper, and fiber products	9.7
Colleges and universities	6.1
Forestry	5.3
Veneer and plywood	5.1
Wood preservation	5.1
Engineering	4.3
Adhesives	3.8
Chemicals	3.8
Millwork	3.2
Packaging and containers	3.2
Furniture and fixtures	1.9
Lumber and veneer drying	1.9
Machinery manufacture	1.6
Publishing	1.6
Home building	1.3
Wood products, unspecified	1.1
Students	1.1
Other, each less than 1 per cent (Roofing; aircraft; boatbuilding; paints, varnishes, lacquers, and pigments; poles; roof structures; high frequency heating; pianos; printing ink; ties; etc.)	7.9

Membership Percentages by Titles

Presidents, Vice Presidents, Assistants to President	19.9
Engineers (all grades)	11.6
Directors of Research	10.8
General Managers, Assistant Managers, Superintendents, Assistant Superintendents	10.5
Deans, Professors, Instructors	6.1
Chemists (all grades)	5.8
Technical Directors, Directors of Technical Service	5.5
Foresters (all classifications)	5.3
Secretaries, Treasurers, Cost Accountants	5.0
Forest Products Technologists	4.4
Sales Managers, Purchasing Directors	3.3
Research Technicians	1.4
Editors	1.1
Students	1.1
Other, each less than 1 per cent (Physicists, Economists, Pathologists, Packaging Specialists, Personnel Managers, Special Representatives, Salesmen, Kiln Supervisors, etc.)	8.2

Membership Percentages by Grades

Voting Members	95.0
Associate Members	3.6
Supporting Members	1.4

Membership Percentages by Society Regions

North-central	29.6
Northwest	22.3
Northeast	20.9
Southeast	12.1
South-central	9.9
Southwest	5.2

Membership Percentages by Bodies Politic

Wisconsin	10.0
Washington	8.3
Illinois and Oregon, each	8.0
District of Columbia	5.4
New York	5.3
British Columbia and Calif., each	4.7
Michigan	4.4
New Jersey	3.9
Ohio and Pennsylvania, each	2.8
Alabama and Indiana, each	2.2
Massachusetts	1.9
Ontario and Tennessee, each	1.7
Iowa, New Hampshire, Quebec, Texas, and Virginia, each	1.4
Arkansas, Connecticut, Florida, Georgia, Louisiana, Maryland, Missouri, and North Carolina, each	1.1
Kentucky, Maine, and Minn., each	0.8
Idaho, Mississippi, Montana, and Utah, each	0.5
Delaware, Hawaii, New Brunswick, South Carolina, Vermont, and West Virginia, each	0.3

First National Meeting

The first general meeting for members of the Forest Products Research Society is scheduled for late October in Chicago. Plans are still in

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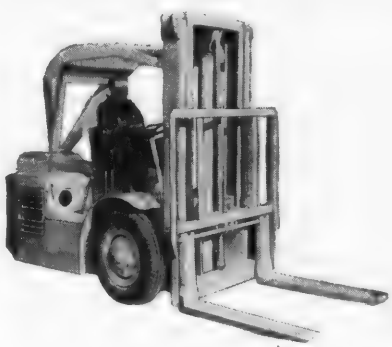

the formative stage; however, the tentative program now being arranged will extend at least two days.

This meeting will provide a focal point out of which the next year's work by the Society will originate. The papers, covering a wide variety of subjects concerned with current research and development in the forest products industries, will be reprinted for FPRS members. A special effort is being made to have papers in concise, practical presentation form, so that their contents will be of equal value to technicians, production workers in shops and mills, or consumers.

Anyone who is interested in offering a paper for the October agenda should communicate with the Secretary-Treasurer, forwarding the title and an outline of the contents.

First Section Formed

A Pacific Northwest Section of the Forest Products Research Society was established by action taken during the meeting of the Associated Forest Products Technologists at the Hotel Winthrop in Tacoma, Washington on Tuesday, May 27. Approximately 125 attended the third meeting of the AFPT which has been active during the past several years in the field of west coast and national forest products development; technical and business sessions of the group convened during the afternoon and evening.

The afternoon program, starting at 1:30 p.m., was devoted entirely to a symposium on adhesives for the woodworking industries. The arrangements for the symposium were made with the Technical Committee of the Plastic Materials Manufacturers' Association which appointed Charles E. Rozema as their representative.

Rozema presided at the technical meeting on adhesives and opened the program with a short discussion of "What is a Glued-Up Product?", classifying adhesives in general as to their moisture and weather resistance. He next introduced speakers who discussed topics as follows: Herbert H. Clarke, "Adhesives of Low Water Resistance" (Protein and carbohydrate class of raw materials); H. B. DeWaide, "Adhesives of Moderate Water Resistance" (Amine-aldehyde resinal adhesives); John Bogner, "Adhesives of Maximum Resistance to Moisture and Weather" (Phenolic-aldehyde resin adhesives); Albert Golick, "Special Adhesives" (Those not covered by the previous speakers); Arthur J. Norton, "The Challenge of Adhesive Manufacturers to the Woodworking Industry"; and Clark C. Heritage, "The Challenge of the Woodworking Industry to the Manufacturers of Adhesives".

Chairman Rozema closed the session with a brief summary of the afternoon's discussions.

Following the technical session, a business meeting of the Associated Forest Products Technologists was called to order by AFPT President Bror L. Grondal, who discussed briefly the accomplishments of this organization to date and called for discussion on the subject of winding up the affairs of the AFPT since the organization had apparently served its purpose. The opinion of the group was that their needs could be better served by the Pacific Northwest Section of the Forest Products Research Society which had been granted on petition of a number from the Pacific Northwest. Professor Grondal then turned the meeting over to Edward G. Locke, Pacific Northwest representative on the executive board of the Forest Products Research Society, who acted as temporary chairman and appointed a nominating committee for a chairman and secretary-treasurer of the local section. This committee reported back at the close of the meeting and Richard N. Hammond was elected as chairman, Clarence D. Stone as secretary-treasurer.

A by-law committee and program committee for the next meeting were appointed by the new chairman.

Following the business meeting a short social hour was held. After dinner a general discussion was given by George F. Cornwall on wood utilization.

It is the plan of the Pacific Northwest section to hold two or more regional meetings per year; alternately between the Puget Sound area and the Columbia River area. Every member of the Society in good standing, who lives in the Paci-

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fic Northwest, is automatically entitled to membership in the Pacific Northwest Section, is entitled to membership in that Section, but such affiliation is not mandatory.

The officers of the Associated Forest Products Technologists who were responsible for the present meeting are President Bror Grondal, Professor of Forest Products, University of Washington, Vice-President P. B. Proctor, Professor of Forest Products at Oregon State College, Treasurer Edward G. Locke, Pacific Northwest Forest and Range Experiment Station, and Secretary Arthur L. Mottet, Development Department, Long Bell Lumber Company.

United Nations Wood Chemistry

The Forestry and Forest Products Division of the Food and Agriculture Organization within the UN recently sponsored a meeting concerned with the world situation in the chemistry of wood. Diivsion Director Marcel Leloup called together a group of eighteen technical representatives, including the Forest Products Research Society, for an informal discussion in New York in February. Dr. Herman F. Mark, Polytechnic Institute of Brooklyn presided.

Forty-seven member nations (with the exception of the U. S. S. R.) participate in the FAO; an organization which serves in a technical advisory capacity. Besides the possible formation at a future date of a subcommittee on wood chemistry under Director Leloup, provisions for subcommittees on mechanical wood technology, tropical forests, research and education, and forest products statistics are under consideration.

Dr. Egon Glesinger, Chief of the Forest Products Branch of the F & FP Division, reported on world cut and consumption of wood. Of the 1,200,000,000 tons now cut annually in the World's forests, only 175,000,000 tons reach consumers as lumber, plywood, crossties, etc., and 25,000,000 tons are converted into pulp products. In tonnage, this is in a category with metals, petroleum and foods. The World's forests of 8,000,000,000 acres, if properly managed, could yield 8,000,000,000 tons of raw wood, but much of this would not be suitable for lumber and related manufacture. Therefore, wood chemistry must devise methods for using more of the wood that is now wasted.

Director Leloup called attention to the fact that there must be an integration of forestry and forest products. Foresters must grow trees that will be best suited to the needs of future industry.

The meeting discussed possible activities of an FAO subcommittee on wood chemistry as follows:

1. Clearing house activities.
2. Advisory activities of the subcommittee to FAO and to member governments in matters of wood chemistry.
3. Initiatives of the subcommittee to induce FAO and governments to adopt certain measures.

Further discussion took up the feasibility of an "International Congress of Wood" with a possible meeting date during the latter part of 1947 in New York. An active European subcommittee on wood chemistry under the chairmanship of Porfessor Ladislav J. Rys, Professor of Chemistry, Prague, Czechoslovakia, reported on recent meetings at Zurich, Stockholm, and Oslo. Besides a North American subcommittee on wood chemistry, including Canadian representation, to be formed by Professor Mark, plans call for similar action in South America, Asia, etc.

Supporting Membership

Besides providing the membership grades of *voting* and *associate*, both of which are open to individuals at annual dues of ten dollars, the Society included a *supporting* membership. This is available to any organization or individual who financially assists the Society through the payment of larger dues; the annual fee for the supporting member is one hundred dollars, which in turn includes all the rights and privileges of voting members, except those of holding office and voting.

In order that the Forest Products Research Society adequately serves its members and the industry it must plan shortly to establish a full-time secretarial staff, abstracting service, and the sponsorship of national and sectional meet-

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ings. Dues paid by the voting and associate members will obviously not be sufficient for the maintenance of all the forementioned services; a much larger fund is needed to finance soundly a strong program by the Forest Products Research Society. The ten dollar dues for individuals was established to allow as broad a membership as possible, because the primary purpose of the organization is to make available current technical data to those who produce or utilize forest products.

Within the past several weeks a number of supporting membership fees of one hundred dollars have been received from research institutions, forest products manufacturing firms and equipment suppliers. This contribution is similar to the sustaining or industrial memberships provided by other non-profit societies and is deductible from federal income tax returns. Such support is especially important now because these funds will provide monies needed during the initial organizational period.

Although no campaign has been launched to obtain supporting members, it is hoped that many organizations who are interested in assisting the research, development, production and utilization for forest products will apply for supporting memberships.

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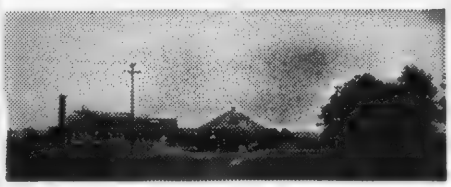

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MONTHLY BULLETIN—JULY 1947*

Second Meeting of the Executive Board

Members of the Executive Board met on June 13 and 14 at the Hotel Loraine, Madison, Wisconsin; the meeting convened following the Wood Industries Conference of the American Society of Mechanical Engineers, where FPRS President Fred W. Gottschalk accepted an invitation to speak at the ASME banquet on the subject of functions and operations of our new Society.

The two-day meeting of the Board developed plans with regard to the establishment of local sections, the appointment of committees, and the preparation of an outline for the national meeting scheduled during October in Chicago.

The Board reviewed the current activities of the Society and the formation of the first section, the Pacific-Northwest Section, on May 27 at Tacoma; this is fully described in the June issue of the Monthly Bulletin. The program undertaken by the West Coast group, including an afternoon symposium by six speakers on glue and an evening banquet with a speaker on the chemical recovery and utilization of forest products, was reported to be of great interest to the 125 in attendance. The Board approved plans for the establishment of at least two similar sections in other regions which will hold two to four meetings annually. Regional board members are responsible for the organization and general operation of local sections. Any ten voting members in an area can petition for authority to create an active local meeting group.

Committees to handle the fields of membership, publications, abstracting, and the local arrangements for the national meeting will be announced soon. The Board placed Vice-President George A. Garratt in charge of the technical details of the October national convention. Three sessions which include a variety of the papers are to be scheduled; these will cover:

Chemical utilization of wood.
Engineering aspects of wood use.
Seasoning and preservation.

Besides the three technical sessions, consideration is being given to an appropriate evening dinner meeting and possible plant inspection trips in Chicago for those who care to remain after the presentation of the papers and reports.

Review

Passage of Liquids, Vapors, and Dissolved Materials Through Softwoods. By Alfred J. Stamm. U. S. Dept. Agric. Tech. Bul. 929. 80 pp., incl. illus., tables, and Appendix. 1946.

Although prepared for publication in 1940 and dated October, 1946, this bulletin did not become available until 1947 due to deferment because of war activities. The purpose of the publication is to assemble necessary wood capillary-structural data and to present approximate calculations covering the differences in structure effective for the passage of liquids, vapors, and solutes through wood under the motivating forces of diffusion and of pressure permeability. The analysis is confined to the softwoods (Gymnosperms), because sufficient capillary data are not available for the more complex hardwoods (Dicotyledons). Wood is made up of different types of capillaries (passageways) varying in size from structures that are visible to the unaided eye down to capillaries that approach molecular dimensions. An understanding of the nature of the various capillary components of wood and the extent to which each is effective in controlling the passage of liquids, vapors, and dissolved materials through wood under different treating conditions should be of major importance to the further development of the processes for seasoning wood, the penetration of chips with

* Prepared by the Society; reprinted from *Wood* Magazine.

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chemicals in pulping, and the penetration of wood with preservatives, fire retardants, and antishrink chemicals.

The author discusses the capillaries represented by the cavities of wood fibers (tracheids), bordered pits, pit pores (permanent perforations) of the limiting membranes between fiber cavities, resin ducts, wood rays, and transient cell-wall capillaries that exist only in the presence of a swelling agent such as water. In connection with the transient cell-wall capillaries, the cell wall is conceived to be made up of bundles of threadlike units known as *fibrils* that incline more or less to the fiber direction, with an outer layer at right angles to the fiber axis. The fibrils are made up of smaller spindle-shaped particles known as *fusiform bodies,* which in turn are composed of bundles of threadlike molecules known as *micelles.* X-ray measurements have shown that the absorption of water by cellulose fibers takes place between the micelles but not within the micelles. The spaces between the micelles exist only when the wood is swollen by an agent, such as water, and disappear as the agent is removed; to emphasize this fact, the author refers to them as transient capillaries. Although the radii of these transient capillaries approach molecular sizes, they are effective in the diffusion of aqueous solutes having relatively small molecules. The permeability effects of longitudinal resin ducts are considered not to be significant, and the wood rays, except in the case of some species of pine, are not very effective in permitting passage of materials into wood. Average capillary-dimension data and their sources are tabulated for the heartwood of a softwood with a swollen-volume specific gravity of 0.365, and the discussion of the measurements and calculations made in obtaining these values is given in considerable detail in the Appendix for those who wish to gain a complete understanding of the subject.

The phenomenon of diffusion (the spontaneous equalization of concentration) is analagous to the conduction of an electric current. Using basic electrical principles, diffusion is calulated for complex passageways that may be in series and parallel combinations. Formulas for longitudinal and transverse diffusion through a swollen block of unit length and cross section are given, and sample calculations for diffusion of solutes into water-saturated heartwood are presented. The diffusion of solutes into heartwood saturated with a non-swelling solvent is discussed.

The drying of heartwood is discussed in considerable detail (22 pages of text with figures). The drying of wood is a much more complicated process than the diffusion of a solute into wood that is completely saturated with a polar or a nonpolar liquid. These complications undoubtedly arise from the complex structure of wood. In the drying of wood, the dimensions of the structural units vary from lamina to lamina in the direction of the drying gradient as the result of accompanying shrinkage. The movement of liquid or vapor in response to the drying gradient is further complicated by the fact that three different driving forces can be effective, namely (1) the flow of liquid through the larger capillaries due to vapor-pressure differences, and (3) the movement of bound water (water held in the cell walls) due to moisture content differences.

The movement of both bound water and water vapor below the fiber-saturation point (that moisture content at which the cell walls are saturated but the cell cavities contain no free water) should be controlled by diffusion. This diffusion is complicated by the fact that two driving forces are involved, and the proportion of each that is effective will vary with changes in the capillary structure due to moisture content changes. In spite of this, the drying process is analyzed, and diffusion values for water vapor and bound water are calculated. Drying diffusion values for transverse diffusion relative to the dimensions of the wood, of green-volume specific gravities of 0.25 to 0.80, are calculated for a temperature of 40° C (104° F), and it is shown that the diffusion values are relatively constant, irrespective of the equilibrium surface moisture content of the wood during the drying process if optimum drying rates are secured. The greatest variation in diffusion values, through the range of surface equilibrium moisture content values of 29% to 0%, occurs in wood with low specific gravities, since vapor diffusion predominates in these woods.

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The effects of changes in the drying temperature upon transverse drying diffusion values were also studied, and it was found that, at temperatures of 50° C (122° F) or less, the diffusion values varied but slightly when the wood was dried from the fiber saturation point to various moisture content values down to the oven-dry condition. At higher temperatures, diffusion values varied more so, particularly as low moisture content values of 6% or less were reached, but even so they are fairly constant for the usual range of moisture content values to which lumber is dried for ordinary uses. This variation is attributed to the predominance of the vapor-diffusion factor at high temperatures.

Average transverse drying diffusion values were calculated for woods of different specific gravities for the moisture content range from the fiber saturation point to an equilibrium moisture content of 10%. Average diffusion values increase appreciably with increase in temperature, particularly for woods of low specific gravity, because of the predominance of vapor diffusion. Vapor diffusion increases much more rapidly than bound-water diffusion as drying temperatures are increased.

The transverse drying diffusion values, relative to unit dimensions of the wood, calculated from drying data are, in general, in good agreement with the theoretical values calculated from capillary structure considerations.

Transverse drying diffusion values, relative to unit dimensions of wood of swollen-volume specific gravity of 0.365, were calculated for a temperature of 40° C (104° F) for several reduced air pressures from capillary structure considerations. Values calculated from capillary structure considerations are considerably higher than diffusion values obtained from drying data, particularly as the air pressure is severely decreased. These discrepancies are probably due to the lack of adequate means for sweeping moisture away from the drying surface under high vacua. Experimental drying at 40° C (104° F) and a 27.74-inch vacuum has shown that drying rates can be increased only a few fold in the transverse direction. As air pressure is reduced, vapor diffusion accounts for a greater and greater proportion of the total diffusion. Diffusion values under high vacua increase to a maximum when the wood has a moisture content of about 6% and then decrease.

Drying diffusion values were also calculated for the longitudinal direction. The longitudinal drying diffusion values increase appreciably with decrease in moisture content, but few data are available for the longitudinal drying of wood, since wood is normally cut so that most of the drying occurs in transverse directions.

Pressure permeability calculations are also presented for systems free from gas-liquid menisci and for systems containing gas-liquid menisci. The passage of virtually free liquids through wood under an external driving force or internal capillary attraction is less subject to fundamental analysis than the diffusion of liquids, vapors, or solutes through wood, since the controlling structure is the most variable part of the wood. Although mathematical values having practical significance cannot be calculated, a few generalizations regarding the nature of the phenomenon and the effective structure are made.

The possibility of collapse due to liquid tension is analyzed, the mechanism of liquid flow is described, and moisture distribution patterns in almost fully-saturated wood and normal green wood are discussed. The moisture-distribution pattern in the drying of most green wood, which contains appreciable amounts of air in the fiber cavities, indicates that the moisture gradient below the fiber-saturation point controls the rate of free water movement above the fiber-saturation point.

Four methods of treating wood with preservatives, fire retardants, anti-shrink chemicals, or chemical seasoning agents are discussed: (1) by diffusion of the treating materials into green wood by soaking in an aqueous solution or packing dry chemical around the green wood; (2) by replacement of the water in green wood with an aqueous solution under a hydrostatic pressure or electrical potential; (3) by capillary rise of the liquid or solution into dry or partially dry wood upon immersion in the solution; or (4) by supplementing capillary rise with the use of a treating cylinder by

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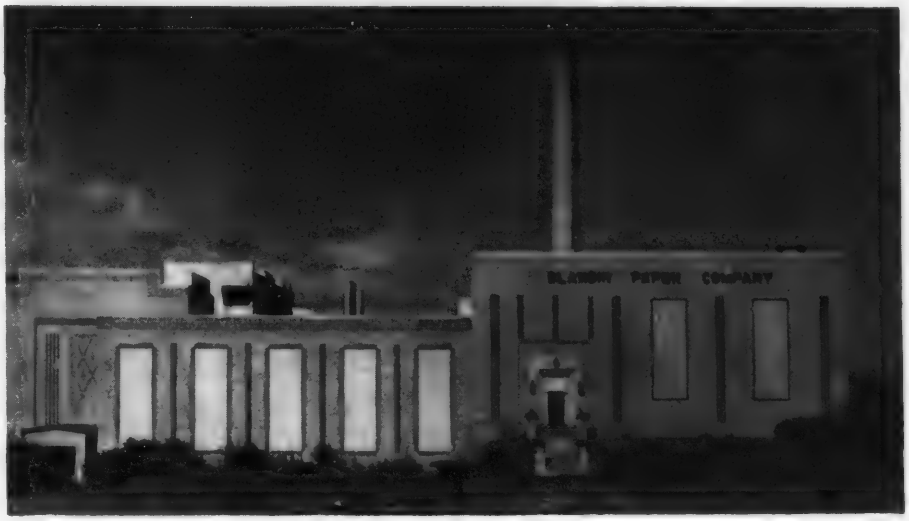

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applying a vacuum to the cylinder containing the wood, running in the treating liquid while maintaining the vacuum, and then applying pressure (so-called full-cell process), or forcing the liquid into the wood against an internal air pressure (so-called empty-cell process).

The so-called osmotic treating methods are not considered, since, unlike the growing plant, cut wood contains no semi-permeable membranes. In the absence of such semi-permeable membranes, the latent osmotic pressure change through a piece of wood manifests itself as a diffusion change.

This theoretical analysis of the means of passage of materials through wood should enable those performing such operations to understand better just what the treatments involve, and it should aid in improving their methods. The chemist, the physicist, and the wood technologist will find this meaty publication challenging and thought provoking.

WILLIAM J. BAKER.

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MONTHLY BULLETIN—AUGUST 1947*

October Meeting

Vice-president George A. Garratt reports that final plans are underway for the first national meeting in Chicago late in October. The two-day meeting, scheduled for Friday and Saturday, Oct. 31 and Nov. 1, is under the direction of the Chicago Arrangement Committees.

The meeting will be in three sessions, with an evening banquet. Starting Friday at 1:00 p. m., the first technical session will deal with "Chemical Utilization of Wood," which will include the manufacture of ethyl alcohol from wood, distillation, pulp and paper, etc. Later in the afternoon speakers at the session on the "Engineering Aspects of Wood Use" will report on prefabrication, adhesives, metal to wood bonding, heavy timber construction and logging.

The third session, "Seasoning and Preservation of Wood" will start at 9:00 a. m., Saturday. New vapor methods of seasoning, current kiln improvements, trends in wood preservation, and developments in wood finishing will be handled by leaders in the particular fields.

Specific details on the evening banquet and the two-day agenda will appear in next month's issue of the Monthly Bulletin.

* Prepared by the Society; reprinted from *Wood* Magazine.

Membership Progress

Since the founding of the Society in January, there are now over 550 Charter Members. Although the majority of the individuals applying for membership are in the *voting* classification at an annual dues of ten dollars, a relatively large proportion of *supporting* memberships at an annual dues of one-hundred dollars are being forwarded by research groups, firms manufacturing forest products, and companies supplying equipment to the wood industries.

A number of members have reported that they are not receiving the membership subscription to *Wood Magazine* which carries the Monthly Bulletin. Because of addressing problems, the publisher cannot forward the magazine until the second month after the membership application is accepted by the Society. In the meantime, the Secretary-Treasurer will mail reprints of the Monthly Bulletin to new members so that all are informed on the current activities of FPRS.

A directory has been prepared for the Society; members who do not have a copy may obtain one by writing direct to the Secretary-Treasurer's office. Listings have been made by cities to facilitate the creation of the sections for local meetings.

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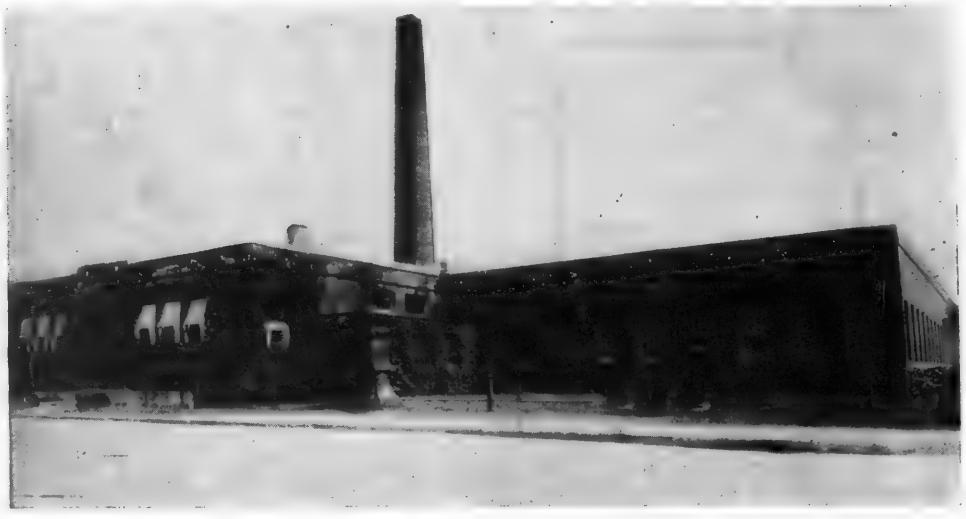

Main Laboratory at Ottawa.

Canada is one of the great timber producing countries of the world and wood products play an important part in its economy. The efficient development and utilization of its forest products involve problems that are of country-wide significance and in the solution of which research plays an important role. Since 1913 forest products research has been carried out in Canada as a federal function through the medium of the Forest Products Laboratories, a unit of the Dominion Forest Service in the Lands, Parks and Forests Branch of the Department of Mines and Resources. The Forest Products Laboratories operate in three centres, the main Laboratories in Ottawa, the Vancouver Laboratory in association with the University of British Columbia at Vancouver, and in Montreal as part of the Pulp and Paper Research Institute.

The work of the Ottawa Laboratories with a staff of 64 full-time employees, is divided into eight main divisions, namely, Timber, Mechanics, Wood Preservation, Wood Chemistry, Timber Physics, Wood Utilization, Lumber Seasoning, Timber Pathology, and Dielectric Heating.

The Vancouver Laboratory is primarily concerned with the research problems of the British Columbia timber industry. Recently this Laboratory—with an enlarged staff of 30 full-time employees—was expanded from two into four divisions, namely, Timber Mechanics, Wood Utilization and Seasoning, Wood Preservation and Pathology and Wood Chemistry.

The Pulp and Paper Research Institute of Canada in Montreal is operated jointly by the Dominion Government, McGill University, and the Canadian Pulp and Paper Association. Its work is directed by a Joint Administrative Committee consisting of representatives of the three member bodies; a General Director and a Director of Technical Research supervise fundamental research on physical chemical lines and also direct the work of post-graduate students. The work of this Institute pertains to technical problems arising in the pulp and paper industry and its work is given practical effect through its close liaison with the Technical and Woodlands Sections of the Canadian Pulp and Paper Association.

† Contribution from the Forest Products Laboratories, Dominion Forest Service, Lands, Parks and Forests Branch, Department of Mines and Resources, Ottawa.

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The Ottawa and Vancouver Laboratories undertake research investigations on the properties of Canadian woods and on technical problems, other than those pertaining to pulp and paper, arising in wood-using industries of Canada. Their work includes such problems as the determination of the mechanical and physical properties of timber and the application of the results to the utilization of wood for heavy and general construction. The laboratories also deal with veneers and plywoods; adhesives; laminated construction; prefabricated panels; wood and fibreboard containers; building codes; standards for structural timber, poles, piling, and wood preservatives; identification and prevention of stain and decay in timber; the preservative treatment of timber against decay, insects, and marine organisms; lumber seasoning by yard drying, dry kilns, or chemicals; application of radio frequency heating to the bonding of plywoods and laminated beams and to the seasoning of special products; chemical utilization of wood waste, by such methods as wood hydrolysis, manufacture into board, and the electro-chemical treatment of waste sulphite liquor; wood technology of Canadian and foreign competing species; industrial investigations with relation to manufacturing methods and equipment; collection of data for use in the integration of wood-using industries with a view to better utilization of raw materials and a curtailment of waste, etc.

Details regarding the various projects which have been set up for the research investigations on these various problems are contained in the Program of Work which the Laboratories publish annually. The current program for the two Laboratories lists the purpose, work accomplished, and work planned for over 95 projects.

In addition to carrying on research projects, members of the Laboratory staff serve on many industrial and standardizing committees. Among these might be mentioned the Executive Committee of the Canadian Standards Association engaged in setting up standards for structural timbers, telegraph poles, piling, wood preservation, prefabricated construction, packaging codes, and wood fibre insulation. The Laboratories are also on the Canadian Government Purchasing Standards Committee, established to set up standards for purchasing various commodities for government use, and on the National Building Code Committee, which drew up a building code for Canada and is now engaged in revising this code and in preparing a simplified code for smaller communities. The Laboratories are represented on many of the special committees of the Woodlands and Technical Sections of the Canadian Pulp and Paper Association. Representatives of the Laboratories also serve on committees of a number of United States organizations, for example, the American Standards Association, the American Society for Testing Materials, the Technical Association of the Pulp and Paper Industry, the American Wood Preservers Association, and the Forest Products Research Society.

The results of the research investigations of the Laboratories are published as Forest Service bulletins and circulars, Laboratory mimeographs, or as articles in trade journals. (In many cases these articles are later issued in reprint form.) Lists of these publications are available upon request. Notification regarding the availability of new publications is normally made through the medium of return address envelopes sent to those on the mailing list. Firms and organizations connected with the production, manufacture, and use of wood in its many forms, who are desirous of having their names added to this mailing list should communicate with the Laboratories at Ottawa or Vancouver.

An important function of the Laboratories is the answering of technical enquiries from the wood-manufacturing and wood-using industries. These requests for technical information and advice are increasing in number. In dealing with them the Laboratories use data obtained from their own researches, supplemented by the information from other sources (especially from forest products laboratories in other countries) which is available in the very complete reference libraries of the Laboratories.

In a short article of this nature it has been possible only to outline very briefly the organization and work of the Forest Products Laboratories of Canada. A more detailed account is contained in the pamphlet entitled "Forest Products Research in Canada", prepared for presentation at the Fifth British Empire Forestry Conference, June, 1947, which is available on request to the Laboratories.

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Report on Germany

Issues of the Bibliography of Scientific and Industrial Reports of the Office of Technical Services, U. S. Department of Commerce, are now available in most large public libraries. The Bibliography gives an abstract of each report and, if the reader desires to secure copies of specific reports, he will find complete directions for ordering them in each issue of the Bibliography. German patents are referred to by the patent numbers as listed in the U. S. Patent Office, and such patents are available directly from the Patent Office in photostat copy at the rate of 20 cents per page.

The reports indexed have been received from civil and military agencies of the United States Government and from cooperating foreign governments. Many of the reports cover information captured in enemy countries. Secrecy restrictions on all reports have been lifted.

The reports cover hundreds of subjects, and no attempt will be made to list them in this Bulletin, but a few of special interest to wood-using industries include the following (P. B. No. refers to the number assigned to the report by the Office of Technical Services):

Manufacture of Pulp and Paper and Related Products from Wood in Western Germany, by J. N. McGovern. P. B. No. 7735.

Production and Fabrication of Glued Wood Products in Western Germany, by R. M. Seborg and H. O. Fleischer. P. B. No. 1318.

Production of Vanillin from Sulfite Waste Liquor, by J. F. Saeman and E. G. Locke. P. B. No. 7749.

Production of Wood Sugar in Germany and its Conversion to Yeast and Alcohol, by J. F. Saeman, E. G. Locke, and G. K. Dickerman. P. B. No. 7736.

Wood Carbonization Industry of Germany, by E. G. Locke and J. F. Saeman. P. B. No. 6355.

Wood and Cellulose Research in Germany, by J. F. Saeman, E. G. Locke, and G. K. Dickerman. P. B. No. 7750.

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MONTHLY BULLETIN—SEPTEMBER 1947*

Chicago Meeting

Plans are nearing completion for the program of the first national meeting of the Forest Products Research Society to be held in the Furniture Club of America, American Furniture Mart Building, Chicago, Illinois, Friday and Saturday, October 31 and November 1, 1947. Registration and a meeting of the Executive Board are scheduled for the morning of the opening day, with sessions for the presentation of technical papers planned for Friday afternoon and Saturday morning. A banquet will be held in The Furniture Club on Friday evening.

Among the speakers who have accepted invitations to participate in the program are Mr. C. C. Heritage, Technical Director, Weyerhaeuser Timber Company, who, with Mr. T. C. Duvall, will present a paper on "Raw Wood Fiber Manufacture"; Mr. Robert J. Seidl, Chemical Engineer, U. S. Forest Products Laboratory, to discuss "Plastic Overlays"; Mr. G. G. Sward, Assistant Director, Scientific Section, National Paint, Varnish and Lacquer Association, speaking on "New Developments in Wood Finishing"; and Mr. Monie S. Hudson, Research Chemist, Taylor–Colquitt Company, who will discuss "The Vapor Drying Process."

Other participants in the technical sessions will include Mr. Clarence W. Farrier, Assistant Director of Housing Research, Experimental Laboratory, American Bridge Company, discussing "New Engineering Problems in the Design of Wood Prefabricated Homes"; Prof. Albert G. H. Dietz, Department of Building Engineering and Construction, Massachusetts Institute of Technology, speaking on "New Developments in the Wood Construction Field"; Mr. Don Brouse, Engineer, U. S. Forest Products Laboratory, on "Postwar Developments in Woodworking Glues"; and Mr. Jac. H. Tigelaar, Director of Research and Tests, Haskelite Manufacturing Corporation, on "Developments in Metal to Wood Bonding." Mr. George M. Hunt, Director, U. S. Forest Products Laboratory, will prepare a paper on the recent British Empire Forestry Conference.

Various other men, prominent in the forest products field, have been invited to participate in the technical program of the meeting, and a complete list of speakers and topics will appear in next month's issue of the "Monthly Bulletin". It is planned to have preprints of the various papers. The papers will subsequently be incorporated into the Proceedings of the Society.

Two committees are handling the meeting arrangements. Mr. Charles H. White, American Walnut Manufacturers Association, is chairman of the Chicago Meeting Committee, and Mr. Edmund J. Laue, U. S. Quartermaster Corps, is chairman of the Chicago Accommodations Committee.

Wilson Appointed Secretary-Treasurer

The resignation on July 25 of Mr. William J. Baker, the first secretary-treasurer, has resulted in action by the Executive Board to establish a permanent office in Madison.

Mr. Thomas R. C. Wilson was appointed to the position of secretary-treasurer and approval was granted for stenographic service. With the membership of the Society well past the 500 mark for Charter Members, the duties of the office have increased beyond that of contributed time operation established in the formative period. Mr. Wilson has accepted a part-time, salaried position with the provision that he will also continue his regular business of consulting engineering. The Society is fortunate in being able to have Mr. Wilson direct the office at Madison; his knowledge of the forest products industries will be especially helpful.

Mr. Baker also resigned from his position at the U. S. Forest Products Laboratory and has accepted a new opening at the Oregon Forest Products Laboratory, Corvallis, Oregon, where he formerly was a professor. The Society is in-

* Prepared by the Society; reprinted from *Wood* Magazine.

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Charter Membership Opportunity Expires

September 30 is the closing date for the Charter period. During the first eight months of its existence, over 575 members have been accepted by the Society; in addition, a great number are expected to join in September.

The Society is basically an organization of individuals who are actively engaged in research, development, production or utilization; the annual dues of ten dollars for Charter Voting members has been kept low purposely to permit a broad membership. A number of organizations interested in supporting the work undertaken by the Society have become Charter Supporting members at an annual dues of one-hundred dollars. A few individuals cannot provide abstracting service, hold national meetings, or publish proceedings, but the financial support through membership makes these things available to the forest products industries.

debted to Mr. Baker for his generous contribution of evenings and weekends since the Society was organized. He was instrumental in drafting the original guide for the Articles of Association and By-laws when serving as secretary of the Organizational Committee that met in Madison on January 3. Mr. Baker has asked that he be assigned Society work in the Pacific Northwest region.

The rapid growth of FPRS has added tremendously to the work handled at our Madison office. The treasury has a substantial cash balance to provide for operating the organization during the year. Secretarial details such as the accounting for funds, membership applications, general correspondence with members, and the membership subscription to *Wood Magazine* are all part of the service performed.

Foreign Memberships Accepted

Memberships for residents of foreign countries are being accepted by the Society. This action was taken by the Executive Board in order that those interested in the work of the Society could participate as Charter Members.

A resolution by the FPRS at an early meeting had limited membership to residents of the United States, its possessions, and Canada, because the secretary could not handle the extra accounting and correspondence.

Members outside of the United States and Canada will also receive a membership subscription to *Wood Magazine* which carries the "Monthly Bulletin" of the Society.

Applications, or a duly executed facsimile thereof, must be mailed to the secretary-treasurer at Madison on or before September 30, 1947.

The dues must be paid in U. S. funds; the international money order has been suggested as a reliable and convenient means of exchange.

United Nations Mechanical Wood Technology

In accordance with the recommendations of the Copenhagen Session of the 1946 Annual Conference of the Food and Agriculture Organization of the United Nations, an FAO Subcommittee on Mechanical Wood Technology has been established, under the Chairmanship of Mr. J. Campredon, Chef des Services Centraux d'Essai des Bois, Paris, France. A meeting of the European representatives was held in Zurich, Switzerland, on January 21–24, 1947, while the American members of the Sub-committee held their first session in Washington, D. C. on July 7–19. Membership in the American Group included representatives of the U. S. Forest Products Laboratory, Forest Products Laboratories of Canada, National Lumber Manufacturers Association, National Bureau of Standards, National Housing Agency, Yale School of Forestry, and Corporacion de Fomento de la Produccion, Chile. The Director and other representatives of the FAO Division of Forestry and Forest Products also participated in the program.

At the opening session of the Washington meeting, Chairman Campredon reviewed the results achieved by the European group in its January meeting. The work initiated at the Zurich session included authorization for the distribution to member nations of FAO of a

We welcome
this opportunity
to commend
the efforts
and progress
of the
Forest Products
Research Society

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questionnaire on Technical Standards in the field of Wood Utilization, including "rules governing timber-work and the technological classification of lumber" and standardization of physical and mechanical tests. The European group had made also several proposals relating to the standardization of dimensions of timber test specimens and had authorized Mr. John Latham of the British Forest Products Research Laboratory to prepare an initial report on methods of testing wood, including specific proposals for the international standardization of axial compression, static bending, tension parallel to grain, and shearing tests. In line with the discussion of the improvement of methods used in the construction of dwelling units, Dr. M. Schlager of Austria had been instructed to compile a comprehensive survey of the use of wood in the construction of prefabricated houses. Finally, the subcommittee had authorized Chairman Campredon to undertake the preparation of a glossary of technical terms used in tests and construction work, proceeding from the French terminology already in use to the formulation of equivalent terms in English and German.

The Washington meeting discussed the problem of international standardization of mechanical timber testing methods, without making any specific recommendations. While conceding the possibility of ready agreement on a number of points as regards specimen sizes and test methods, it was considered that any final proposals for standardization should be deferred, pending a review of methods of testing used in different countries and a study of the correlation of results obtained with specimens of different shapes and with different conditions of testing. It was planned to review the report being prepared by Mr. Latham, to determine the points on which agreement is already apparent, as well as those which need further consideration.

Agreement was reached as to the need for an appropriate international glossary of technical terms related to the various phases of wood technology, developed on a more extensive scale than the list of terms and definitions being compiled by Mr. Campredon. It was considered that such pertinent glossaries as now exist should be extended and made available in English, French, Spanish, German and possibly other languages. The members of the subcommittee expressed the opinion that this project should be undertaken by the FAO Forest Products Branch, in collaboration with selected individuals and organizations.

As a means of partly alleviating the serious shortages of lumber and allied building materials in Europe and other regions, consideration was given to the savings being effected in the United States by the use of sound engineering designs and factory production methods in the building construction field. The subcommittee recommended that FAO undertake the compilation of available information on prefabrication and other aspects of dwelling construction, and arrange with competent experts for the preparation of a report on the subject.

Considerable time was given to a discussion of lumber sizes, in view of the interest of the European members of the subcommittee in standardization of cutting dimensions as a means of better utilization of timber. The American group, while concurring in the desirability of extending size standardization wherever possible, was firm in its stand that the highly technical and controversial nature of the problem necessitates further detailed study and consideration by the various countries concerned before any agreement can be reached. To this end, it was recommended that FAO facilitate the interchange, among interested countries, of information on the standards of width, thickness and length now in effect for the main types of lumber produced. Following the circulation of such information, the possibilities for international standardization of lumber sizes can be determined.

Consideration was given to the raw materials and processes used in manufacture of fiberboard and agglomerated boards in America and Europe, with special emphasis on small-scale manufacture and waste utilization. Several European countries were reported to be contemplating the production of fiberboard as a means of speeding up reconstruction and building. It was proposed that FAO should endeavor to obtain information on existing fiberboard plants, with reference to methods of manufac-

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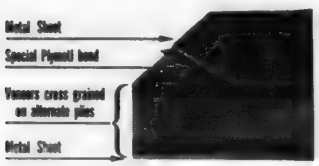

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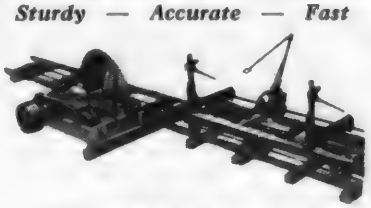

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ture, capacities, supplies of raw material, and other pertinent data. Furthermore, in recognition of the need for standardization of methods for testing wood—and fiber-based boards, it was recommended that the U. S. Forest Products Laboratory should study the problem and make proposals for the preparation of an international standard pertaining to the testing of such boards.

In connection with the discussion of ways and means of increasing the serviceability of wood used in building construction, attention was drawn to the lack of information in America concerning the effectiveness of certain preservatives and preservative methods originating in Europe and elsewhere. The problem of treating wood to obtain satisfactory service in certain tropical regions was also considered. Further, it was emphasized that sound construction methods constitute the most important primary means of obtaining adequate protection against decay and insect hazards. The need was expressed for the free interchange on an international basis, of significant information on construction methods and practices for the adequate protection of wood structures, and on the use of preservatives, paints and varnishes, fire-retardents, water-repellents, and other protective materials. To this end, it was recommended that the FAO Forest Products Branch serve as a clearing-house for pertinent information on methods of timber protection employed in building construction throughout the world.

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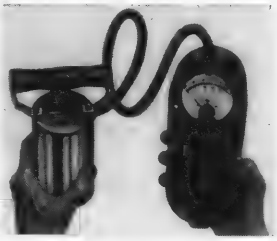

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MONTHLY BULLETIN—OCTOBER 1947*

The First National Meeting to Be Held at Chicago

TECHNICAL PROGRAM†

Friday, October 31, 1:00 p. m.

General Subject: Chemical Utilization of Wood and Integrated Logging

Whole Wood Fiber Manufacture, C. C. Heritage, Technical Director, and T. C. Duvall, Manager, Development Department, Wood Conversion Company, Cloquet, Minnesota.

Certain Problems in the Field of Lignin Chemistry, Harry F. Lewis, Research Associate, The Institute of Paper Chemistry, Appleton, Wisconsin.

Modern Techniques for Processing Pine Gum, E. L. Patton, Head, Naval Stores Research Division, Bureau of Agricultural and Industrial Chemistry, U. S. Department of Agriculture, New Orleans, Louisiana.

Paper and Plastic Overlays for Veneer and Plywood, Robert J. Seidl, Chemical Engineer, U. S. Forest Products Laboratory, Madison, Wisconsin.

Integrated Utilization—Research Task, J. Alfred Hall, Director, Pacific Northwest Forest and Range Experiment Station, U. S. Forest Service, Portland, Oregon.

Present-day Trends in Logging, Edward P. Stamm, Logging Manager, Crown Zellerbach Corporation, Portland, Oregon.

Pulpwood Logging Developments in Canada, A. Koroleff, Director of Woodlands Research, Pulp and Paper Research Institute of Canada, Montreal, Canada.

General Subject: Engineering Aspects of Wood Use

Influence of Building Codes on Postwar Wood Construction, L. P. Keith, Manager, Chicago Office, National Lumber Manufacturers Association, Chicago, Illinois.

Progress in Wood Construction, Albert G. H. Dietz, Associate Professor, Department of Building Engineering and Construction, Massachusetts Institute of Technology, Cambridge, Massachusetts.

New Engineering Problems in the Design of Wood Prefabricated Homes, Clarence W. Farrier, Assistant Director of Housing Research, Experimental Laboratory, American Bridge Company, Ambridge, Pennsylvania.

Developments in the Postwar Packaging Field, C. J. Carney, Jr., Managing Director, Industrial Packaging Engineers Association of America, Chicago, Illinois.

* Prepared by the Society; reprinted from *Wood* Magazine.

† Corrected before reprinting.

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General Subject: Engineering Aspects of Wood Use—Continued

Something New in Functional Furniture, Erskine H. Courtenay, Director of Sales, Furniture Division, The Mengel Company, Louisville, Kentucky.

Postwar Developments in Woodworking Glues, Don Brouse, Engineer, and R. F. Blomquist, Chemist, U. S. Forest Products Laboratory, Madison, Wisconsin.

Metal to Wood Bonding, Jac. H. Tigelaar, Director of Research and Tests, Haskelite Manufacturing Corporation, Grand Rapids, Michigan.

Use of High Frequency in Woodworking, Paul B. Zottu, Consulting Electronic Engineer and Physicist, Electronic Heating Associates, Newton, Massachusetts.

Friday, October 31, 7:00 p. m.

Evening Banquet.

Saturday, November 1, 9:00 a. m.

General Subject: Preservation and Seasoning, Miscellaneous

Recent Developments in Wood Finishing, G. G. Sward, Assistant Director, Scientific Section, National Paint, Varnish and Lacquer Association, Inc., Washington, D. C.

Characteristics and Related Toxicity of Hydrocarbon Oils, J. A. Vaughan, Research Engineer, Southern Wood Preserving Company, Atlanta, Georgia.

The Use of Treated Car Lumber by the Railroads, Paul D. Brentlinger, Forester, The Pennsylvania Railroad Company, Philadelphia, Pennsylvania.

Fence Posts: An Untapped Market for the Wood Preserver, C. S. Walters, Assistant Professor in Forest Utilization Research, University of Illinois Agricultural Experiment Station, Urbana, Illinois.

Acid-Proofing of Wood, R. H. Bescher, Manager, Technical Department, Wood Preserving Division, Koppers Company, Inc., Orrville, Ohio.

Vapor Drying: The Artificial Seasoning of Wood in Vapor of Organic Chemicals, Monie S. Hudson, Research Chemist, Taylor–Colquitt Company, Spartanburg, South Carolina.

Aspects of Kiln Design, John B. Welch, Vice President, Standard Dry Kiln Company, Indianapolis, Indiana.

Tungsten Carbide Developments in the Woodworking Field, M. A. Corti, President, Marcoloy, Inc., Springdale, Connecticut.

Manufacture of Tight Cooperage Plywood, E. George Stern, Director, Wood Research Laboratory, Virginia Polytechnic Institute, Blacksburg, Virginia.

The Fifth British Empire Forestry Conference, George M. Hunt, Director, U. S. Forest Products Laboratory, Madison, Wisconsin.

The Wood Forum, Charles G. Tickle, Editor, *Timber and Plywood,* London, England.

Saturday, November 1, 11:00 a. m.

Business meeting.

Saturday, November 1, 12:30 p. m.

Adjournment.

General Announcements

Final details have been completed for the two-day Forest Products Research Society meeting to be held at the facilities of the Furniture Club of America in the American Furniture Mart Building, 666 North Lake Shore Drive, adjacent to the Chicago Campus of Northwestern University. The entire program on October 31, Friday, and November 1, Saturday, is open to all. Adequate hotel accommodations are available. High lights include three technical sessions, an informal banquet on Friday evening, and a table-top exhibit of new products of wood and equipment used by the industry. To enable the Chicago Meeting Committee to provide adequate service, everyone planning to attend should write Chairman Charles H. White immediately.

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Registration

There will be no registration fee for members or non-members. Registration facilities will be open at 9:00 a. m. Friday. Those who have registered in advance by mail may receive their official badge at the advance registration desk. Meetings and planned tours are open to all registrants. Ladies are invited to participate in any of the meetings and other activities listed on the program.

Preprinting of Papers

Preprints of all papers will be available at the registration desk, without charge, to the press and members of FPRS. Guests and visitors may obtain preprints at a small charge.

Meeting Facilities

The Furniture Club facilities on the 17th floor of the American Furniture Mart Building where the FPRS meeting will be held include the main lounge for registration and a large connecting meeting room which will seat 300 people with rostrum and excellent public address system for the technical sessions. The banquet on Friday evening will be held in the main dining room. Lunch at noon Friday and Saturday may be obtained at the Club or a public cafeteria on the 17th floor of the building; however, ladies are invited to the luncheon and tour of Marshall Field & Co. Friday noon.

GENERAL PROGRAM

Friday, October 31

9:00 a. m. New Registration.

10:30 a.m. Conducted tour of the American Furniture Mart.

This tour of the world's largest furniture display building will demonstrate how the nation's leading furniture and appliance manufacturers show their latest products and how the building organization is set up to handle thousands of carloads of furniture and appliances for the markets. The trip will leave from the Society registration desk and return there in approximately one hour.

12:00 Noon Table-top exhibit opened.

12:30 p. m. A Special for the Ladies Only.

Lunch at Marshall Field & Co. and a behind-the-scenes tour of this great store is a special ladies' program. Detailed information may be obtained at the registration desk. There will be a $1 service charge. The trip will terminate before 5:00 p. m. All women registered, whether visitors or members, are welcome on this or the other events of the two-day meeting.

1:00 p. m. Technical Program.

Session on Chemical Utilization of Wood and Integrated Logging.

Session on Engineering Aspects of Wood Use.

7:00 p. m. Informal Banquet.

Tickets for the banquet will be mailed for paid reservations received through October 20. After that date, reserved tickets may be called for at the advance registration desk on meeting day. Banquet tickets issued prior to meeting day, October 31, will cost $4 each; address your pre-registration for banquet tickets requests to the chairman of the Chicago Meeting Committee, Mr. Charles H. White, c/o American Walnut Manufacturers Association, 666 North Lake Shore Drive, Chicago, enclosing your check made out to the Forest Products Research Society. Tickets purchased on meeting day will be at a fee of $5.50 each if additional facilities are available at that time. The deadline for the sale of tickets was established in the spirit of service because the caterer must provide sufficient chefs, waiters, and food. Inasmuch as the banquet is Friday, selection of a fish or meat entree must be made when purchasing tickets. The banquet menu is as follows:

Supreme of Fruit
Cream of Mushroom Soup
Roast Prime Ribs of Beef Au Jus
or
Broiled Lake Superior Whitefish
New Peas
Rissole Potatoes
Princesse Salad
Green Apple Pie and Cheese
Coffee

The banquet is open to all member and non-member registrants and their ladies.

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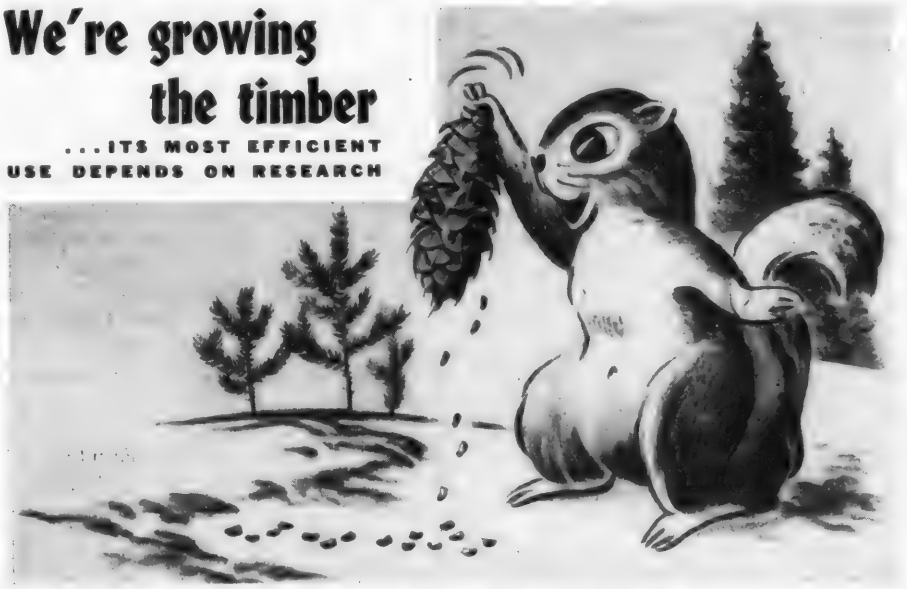

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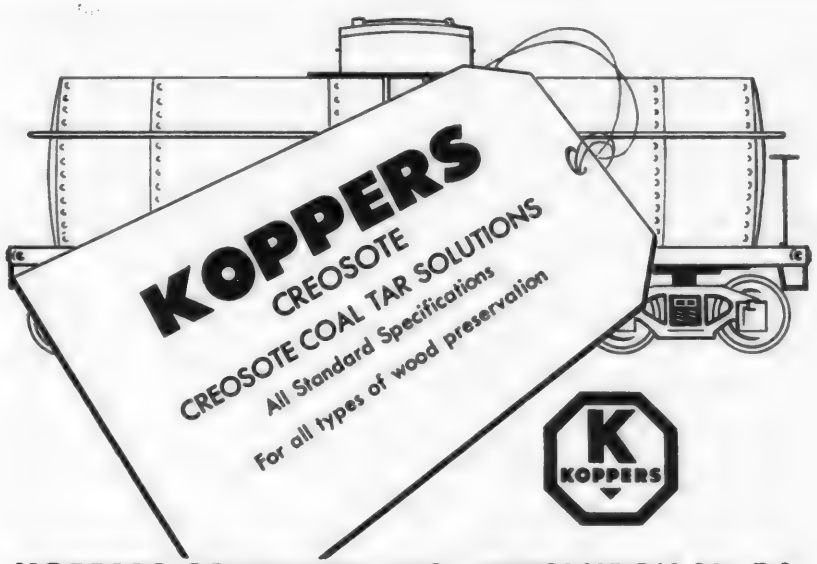

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Saturday, November 1

9:00 a. m. Technical Program.
Session on Preservation and Seasoning.
11:00 a. m. Business meeting.
12:30 p. m. Adjournment.
2:00 p. m. Football: Northwestern University vs. University of Wisconsin.

Although this is not an official part of the program, it is suggested as an event to take in before leaving the Chicago area. Tickets for the game to be played at Evanston, Illinois, are available at $3.50 each. Order your tickets now by writing to the Northwestern University, Football Ticket Office, Dyche Stadium, Evanston, Illinois. The Chicago Northwestern Railroad and the Rapid Transit Company (elevated) provide service from the Chicago loop to Dyche Stadium, Evanston.

Mail and Telegrams

It is recommended that all communications be addressed to your hotel. The registration desk of the Society will attempt to locate registrants in emergency but it can accept no responsibility for such service.

Forest Products Table-Top Exhibit

Any producer of forest products, supplier of equipment or materials used by the forest products industries, consumers of wood, laboratories in the wood field, etc., can exhibit. The purpose of the table-top display is to provide information to those concerned with forest products development, production, or utilization. Getting authoritative information to the wood industry is a major objective.

Press Facilities

The Press Committee will be on hand at the registration desk. Preprints of all technical papers and information of special features of the meeting will be available to the trade press and newspapers.

Local Transportation

Taxicabs and the bus service of the Chicago Motor Coach Company are the most satisfactory means of reaching the American Furniture Mart Building or the nearby hotels. If in doubt upon arrival at Chicago rail or airline depots, inquire as to the convenient transportation to 666 North Lake Shore Drive, Chicago. The northbound route of the Ohio Street Depots motor coach connects with the Union Station, the Chicago and Northwestern Railroad Station, and the majority of the hotels in the Mart area. The 667 North McClurg Court door, west entrance, of the American Furniture Mart Building, is preferred for cabs and automobile parking.

Hotel Accommodations

The hotels in the vicinity of the Furniture Mart have been contacted and have agreed to accept reservations for those attending the meeting.

It is suggested that each member make his own reservation directly with the hotel he selects. State that you are attending the Forest Products Research Society meeting and indicate exact dates you will desire your accommodations. The Allerton Hotel has been established as headquarters; however, this hotel cannot accommodate the entire group attending the FPRS meeting. You will receive your confirmation direct from the hotel.

The Chicago Meeting and Accommodations Committees urgently request you to immediately advise Chairman Charles H. White of your intention of attending and enclose your check for banquet tickets.

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Incorporation, Articles of Association, and By-Laws

Incorporated August 8, 1947 under the articles of the General Not for Profit Corporation Act in the State of Illinois.

Incorporators of said corporation are:

Fred W. Gottschalk
George A. Garratt
William J. Baker

Registered Office is Room 2034, 332 South Michigan Avenue, Chicago 4, Illinois, and the Registered Agent is Fred W. Gottschalk.

The first Executive Board shall be:

Fred W. Gottschalk
George A. Garratt
William J. Baker
Bror L. Grondal
Edward G. Locke
James F. Hamilton
Jac. H. Tigelaar
Robert A. Cockrell
Carl A. Rishell
Kenneth G. Chesley

ARTICLES OF ASSOCIATION

ARTICLE I

Name

The name of the Society shall be FOREST PRODUCTS RESEARCH SOCIETY.

ARTICLE II

Objects and Purposes

SECTION 1. The objects and purposes of this Society shall be (1) to facilitate the interchange of information among individuals and organizations who are interested in forest products research, development, or utilization (a) by abstracting papers, reports, and other publications, (b) by publishing and distributing pertinent information, (c) by encouraging cooperation among interested persons, (d) by promoting standard test methods and procedures, (e) by sponsoring meetings for the presentation and discussion of reports of investigations and experiences of its members and others, for the interchange of ideas, and for the broadening of acquaintanceships among individuals interested in forest products research, development, or utilization; and (2) in general to encourage and promote the efficient utilization of wood and other forest products.

SECTION 2. The Society shall be operated on a non-profit basis.

BYLAWS

of the

FOREST PRODUCTS RESEARCH SOCIETY

ARTICLE I

Members

SECTION 1. CLASSES OF MEMBERS. The Society shall consist of Voting Members, Supporting Members, and Associate Members; the qualifications shall be as follows:

A Voting Member shall be any individual who is actively engaged in planning, supervising, or working in any phase of forest products research, development, or utilization. Voting Members shall have all rights and privileges of the Society.

A Supporting Member shall be any organization or individual who financially assists the Society by paying dues in accordance with Article II, Section 1, of these bylaws. Each Supporting Member who is an individual shall have all rights and privileges of a Voting Member. Each organization that is a Supporting Member may designate one representative who shall have all rights and privileges of a Voting Member.

FORESTRY RESEARCH FOUNDATION

(NON-PROFIT CORPORATION)

SERVING THE FORESTRY INTERESTS BOTH PUBLIC AND PRIVATE IN OREGON AND THE PACIFIC NORTHWEST.

ORGANIZED TO FACILITATE, ENCOURAGE AND PROMOTE RESEARCH IN FORESTRY. ASSOCIATED WITH THE OREGON FOREST PRODUCTS LABORATORY.

OFFICE OF THE SECRETARY

SCHOOL OF FORESTRY

OREGON STATE COLLEGE

CORVALLIS, OREGON

An Associate Member shall be any individual who is interested in forest products research, development, or utilization, although not actively engaged in such pursuits. Associate Members shall have all rights and privileges of Voting Members, except those of holding office and voting.

SECTION 2. ELECTION OF MEMBERS. Members shall be elected by action of the Executive Board. An affirmative vote of two-thirds of the directors shall be required for election.

SECTION 3. VOTING RIGHTS. Each Voting Member and the designated representative of each Supporting Member shall be entitled to one vote on each matter submitted to a vote of the members.

SECTION 4. TERMINATION OF MEMBERSHIP. The Executive Board by affirmative vote of two-thirds of all of the members of the Board may suspend or expel a member for cause after an appropriate hearing, and may, by a majority vote of those present at any regularly constituted meeting, terminate the membership of any member who becomes ineligible for membership, or suspend or expel any member who shall be in default in the payment of dues for the period fixed in Article II, Section 3 of these bylaws.

SECTION 5. RESIGNATION. Any member may resign by filing a written resignation with the secretary-treasurer, but such resignation shall not relieve the member so resigning of the obligation to pay any dues theretofore accrued and unpaid.

SECTION 6. REINSTATEMENT. Upon written request signed by a former member and filed with the secretary-treasurer, the Executive Board may by the affirmative vote of two-thirds of the members of the Board reinstate such former member to membership upon such terms as the Board may deem appropriate.

SECTION 7. TRANSFER OF MEMBERSHIP. Membership in this Society is not transferable or assignable.

ARTICLE II

Dues

SECTION 1. FISCAL YEAR DUES. The fiscal year shall begin on April 1 and shall terminate on March 31 of each year. The annual dues, payable during the first two (2) months of the fiscal year, shall be as follows: Voting Members, Ten Dollars ($10.00); Supporting Members, One Hundred Dollars ($100.00); and Associate Members, Ten Dollars ($10.00).

SECTION 2. APPLICATION FOR ADMISSION. An applicant for admission to the Society shall indicate the desired class of membership on the application blank. For applicants who are elected to membership on or after April 1 and prior to January 1, the full amount of the annual dues shall be collected for and applied to the fiscal year in which they are elected. For applicants who are elected to membership on or after January 1 and prior to April 1, the annual dues collected shall apply to the whole of the next fiscal year as well as to the balance of the fiscal year in which they are elected, but publications of the fiscal year of election are not included in the benefits of membership. Dues submitted with application blanks shall be returned to applicants who are not elected to the Society.

SECTION 3. UNPAID DUES. Any member whose dues are unpaid on July 1 shall not receive publications or releases of the Society, and, if the member's dues are in arrears on March 31, the membership shall be cancelled, except as provided for in Section 4 of this Article.

SECTION 4. EXTENSION. The Executive Board by a majority vote may extend the time for payment of the dues of any Voting Member who is unable to pay them within the prescribed time.

ARTICLE III

Executive Officers

SECTION 1. EXECUTIVE OFFICERS. The executive officers shall be the president, vice-presidents, last past-president, and a secretary-treasurer.

SECTION 2. PRESIDENTS. The president and first and second vice-presidents shall be elected at each Annual Meeting.

SECTION 3. SECRETARY-TREASURER. The secretary-treasurer shall be appointed by the Executive Board and bonded at the expense of the Society. The secretary-treasurer shall have no vote on the Executive Board.

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SECTION 4. DUAL OFFICES. One person can hold only one office at any given time.

SECTION 5. OTHER EXECUTIVE OFFICERS. The Executive Board may elect or appoint such other offices, including one or more assistant secretaries and one or more assistant treasurers, as it shall deem desirable, such officers to have authority and perform the duties prescribed, from time to time, by the Executive Board.

SECTION 6. ELECTION AND TERM OF OFFICE. The elective executive officers of the Society shall be elected by the Voting Members and designated representative of Supporting Members at the regular Annual Meeting. If the election of officers shall not be held at such meeting, such election shall be held as soon thereafter as convenient. Vacancies may be filled or new offices created and filled at any meeting of the Executive Board. Each officer shall hold office until his successor shall have been duly elected and shall have qualified.

SECTION 7. VACANCY IN PRESIDENT'S OFFICE. In the event of a vacancy in the office of president, the unexpired term of this office shall be completed by the first vice-president.

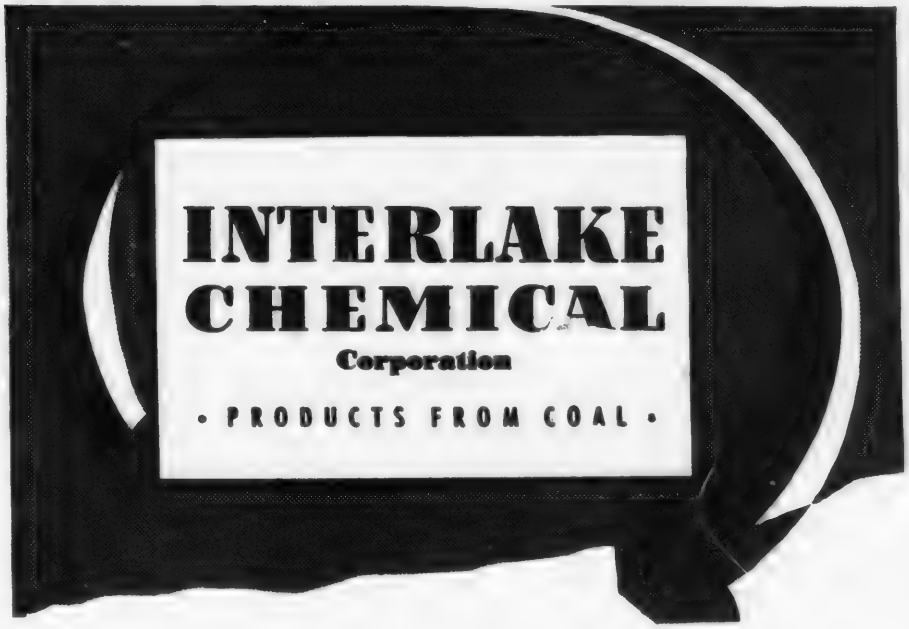
SECTION 8. PRESIDENT. The president shall be the principal executive officer of the Society and shall in general supervise and control all of the business and affairs of the Society. He shall preside at all meetings of the members and of the Executive Board. He may sign, with the secretary-treasurer or any other proper officer of the Society authorized by the Executive Board, any deeds, mortgages, bonds, contracts, or other instruments, which the Executive Board has authorized to be executed, except in cases where the signing and execution thereof shall be expressly delegated by the Executive Board or by these bylaws or by statute to some other officer or agent of the Society; and in general shall perform all duties incident to the office of president and such other duties as may be prescribed by the Executive Board from time to time.

SECTION 9. VICE-PRESIDENTS. In the absence of the president or in the event of his inability or refusal to act, the first vice-president shall perform the duties of the president, and when so acting, shall have all the powers of and be subject to all the restrictions upon the president. Any vice-president shall perform such other duties as from time to time may be assigned to him by the president or by the Executive Board.

SECTION 10. SECRETARY-TREASURER. The secretary-treasurer shall give a bond for the faithful discharge of his duties in such sum and with such surety or sureties as the Executive Board shall determine. He shall have charge and custody of and be responsible for all funds and securities of the Society; receive and give receipts for moneys due and payable to the Society from any source whatsoever, and deposit all such moneys in the name of the Society in such banks, trust companies or other depositaries as shall be selected in accordance with the provisions of Article VIII of these bylaws; and in general perform all the duties incident to the office of secretary-treasurer and such other duties as from time to time may be assigned to him by the president or by the Executive Board.

This officer shall keep the minutes of the meetings of the members and of the Executive Board in one or more books provided for that purpose; see that all notices are duly given in accordance with the provisions of these bylaws or as required by law; be custodian of the corporate records and of the seal of the Society and see that the seal of the Society is affixed to all documents, the execution of which on behalf of the Society under its seal is duly authorized in accordance with the provisions of these bylaws; keep a register of the post office address of each member as furnished by such member; and in general perform all duties incident to the office of secretary-treasurer and such other duties as from time to time may be assigned to him by the president or by the Executive Board.

SECTION 11. ASSISTANT TREASURERS AND ASSISTANT SECRETARIES. If required by the Executive Board, the assistant treasurers shall give bonds for the faithful discharge of their duties in such sums and with such surety or sureties as the Executive Board shall determine. The assistant treasurers and assistant secretaries, in general, shall perform such duties as shall be assigned to them by the treasurer or by the secretary or by the president or the Executive Board.



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ARTICLE IV

Regional Board

SECTION 1. REGIONAL BOARD. A regional board to assist with the management of the Society, consisting of six officers, shall be elected at Annual Meetings as outlined by this Article.

SECTION 2. DESIGNATION OF REGIONS. The regions shall be as follows:

Northwest Region:

Alaska, Idaho, Montana, Oregon, Washington and adjacent Canada.

Northeast Region:

Connecticut, Maine, Massachusetts, New Hampshire, New Jersey, New York, Pennsylvania, Rhode Island, Vermont and adjacent Canada.

North Central Region:

Illinois, Indiana, Iowa, Michigan, Minnesota, Nebraska, North Dakota, Ohio, South Dakota, Wisconsin and adjacent Canada.

Southwest Region:

Arizona, California, Colorado, Nevada, New Mexico, Utah, and Wyoming.

Southeast Region:

Delaware, District of Columbia, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, and West Virginia.

South Central Region:

Alabama, Arkansas, Kansas, Kentucky, Louisiana, Mississippi, Missouri, Oklahoma, Tennessee, and Texas.

SECTION 3. ELECTION AND TERM OF OFFICE. The terms of regional board members shall begin at the close of the Annual Meeting at which they are elected by the Voting Members and the designated representatives of the Supporting Members of that region, and shall continue through the next three (3) Annual Meetings. Each of the Regions designated in Section 2 shall be represented by one (1) Executive Board Member; with elections to be held on three (3) year intervals as shown in Article V, Section 16.

SECTION 4. MEMBERS OUTSIDE OF UNITED STATES AND CANADA. Voting Members and the designated representative of Supporting Members not residing in a designated region shall not qualify to vote for regional board members.

ARTICLE V

Executive Board

SECTION 1. BOARD OF DIRECTORS. The Board of Directors, hereafter designated the Executive Board, shall manage the affairs of the Society.

SECTION 2. MEMBERSHIP OF EXECUTIVE BOARD. The Executive Board shall consist of the president, vice-presidents, last past-president, and the six regional board members.

SECTION 3. MANAGEMENT. The Executive Board shall manage the affairs of the Society and shall have full power to control and regulate all matters not provided for in these bylaws. It shall act on applications for membership; make appropriations for specific purposes; direct the care of surplus funds of the Society; audit the accounts of the secretary-treasurer; and publish the reports and Proceedings of the Society.

SECTION 4. QUORUM. Five (5) members of the Executive Board shall constitute a quorum for the transaction of business at any meeting of the Board, provided, that if less than a majority of the directors are present at said meeting, a majority of the directors present may adjourn the meeting from time to time without further notice.

SECTION 5. MANNER OF ACTING. The act of a majority of the directors present at a meeting at which a quorum is present shall be the act of the Executive Board, except where otherwise provided by law or by these bylaws.

SECTION 6. VACANCIES. Any vacancy occurring in the Executive Board or any directorship to be filled by reason of an increase in the number of directors, shall be filled by the Executive Board. A director elected to fill a vacancy shall be elected for the unexpired term of his predecessor in office.

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SECTION 7. NOTICE. Notice of any special meeting of the Executive Board shall be given at least ten (10) days previously thereto by written notice delivered personally or sent by mail or telegram to each director at his address as shown by the records of the corporation. If mailed, such notice shall be deemed to be delivered when deposited in the United States mail in a sealed envelope so addressed, with postage thereon prepaid. If notice be given by telegram, such notice shall be deemed to be delivered when the telegram is delivered to the telegraph company. Any director may waive notice of any meeting. The attendance of a director at any meeting shall constitute a waiver of notice of such meeting, except where a director attends a meeting for the express purpose of objecting to the transaction of any business because the meeting is not lawfully called or convened. Neither the business to be transacted at, nor the purpose of, any regular or special meeting of the board need be specified in the notice or waiver of notice of such meeting, unless specifically required by law or by these bylaws.

SECTION 8. EMERGENCY ACTION. In the event of emergency, the president can act upon matters of management by mail or telegraph with members of the Executive Board. Questions must be submitted so that a board member may vote as affirmative, negative, or not-voting. Receipt of five (5) affirmative replies shall constitute a quorum. A report of each such vote shall be transmitted, within a reasonable period of time, to each member of the Executive Board.

SECTION 9. REGULAR MEETINGS. A regular annual meeting of the Executive Board shall be held without other notice than this bylaw, immediately after, and at the same place as, the annual meeting of members. The Executive Board may provide by resolution the time and place, either within or without the State of Illinois, for the holding of additional regular meetings of the Board without other notice than such resolution.

SECTION 10. SPECIAL MEETINGS. Special meetings of the Executive Board may be called by or at the request of the president or any two board members. The person or persons authorized to call special meetings of the board may fix any place, either within or without the State of Illinois, as the place for holding any special meeting of the Board called by them.

SECTION 11. PUBLICATIONS. Subject to the action of the Society, the Executive Board may withhold from publication, in whole or in part, discussions, papers, or reports, the propriety or soundness of which is considered questionable.

SECTION 12. VACANCY IN ELECTIVE OFFICE. A vacancy in any elective office, other than that of president, shall be filled by an appointee of the Executive Board. Such an appointee shall not serve beyond the next Annual Meeting unless then elected to fill the remainder of an unexpired term.

SECTION 13. RE-ELECTION. The president, vice -presidents, and regional executive board members shall be ineligible for re-election to the *same* office within three (3) years after the expirations of their respective terms.

SECTION 14. REMOVAL. Any officer or agent elected or appointed by the Executive Board may be removed by the Executive Board whenever in its judgement the best interests of the Society would be served thereby, but such removal shall be without prejudice to the contract rights, if any, of the person so removed.

SECTION 15. COMPENSATION. Executive Board members, as such, shall not receive any stated salaries for their services, but by resolution of the Executive Board, a fixed sum and expenses of attendance, if any, may be allowed for attendance at each regular or special meeting of the Board; provided, that nothing herein contained shall be construed to preclude any director from serving the Society in any other capacity and receiving compensation therefor.

SECTION 16. TERMS OF INITIAL ELECTIVE OFFICERS. The terms of the first or initial elective officers shall terminate at the close of Annual Meetings as follows:

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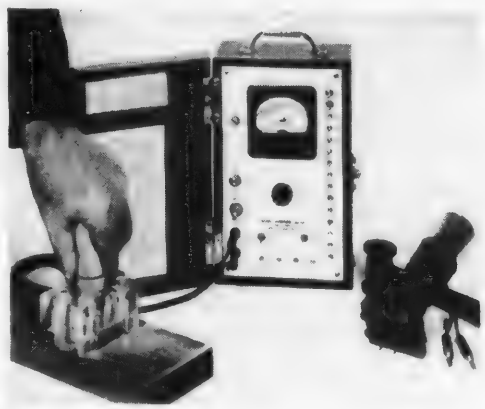

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The moisture measurement is based ***on electrical conductance,*** which varies with moisture ***percentage,*** and ***not on electrical capacitance,*** which varies with the ***weight*** of water content. Therefore the density of wood, whether hickory or the lightest balsa, has negligible effect upon the meter reading. ***Corrections for species are seldom more than a small fraction of the indicated percentage, and usually may be disregarded except for the closest of determinations.*** If the measurement were based on capacitance, which varies with weight and not percentage of moisture, the same meter reading would indicate quite different percentages depending on the density of the wood—far higher percentages for light species than for dense species. And even in the same piece of wood the denser parts would read higher than the lighter parts.

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Office	*Year*
President	1948
Vice-President	1948
Past-Chairman	1948
Northwest Regional Board Member	1948
Northeast Regional Board Member	1948
North-Central Regional Board Member	1949
Southwest Regional Board Member	1949
Southeast Regional Board Member	1950
South-Central Regional Board Member	1950

ARTICLE VI

Meeting of Members

SECTION 1. ANNUAL MEETING. An annual meeting of the members shall be held on one or more succesive days during the month of March in each year, beginning with the year 1948 for the purpose of electing such executive officers and members of the regional board as are then to be elected and for the transaction of such other business as may come before the meeting. The president, vice-presidents, and two (2) regional board members shall be elected at each Annual Meeting.

SECTION 2. SPECIAL MEETING. Special meetings of the members may be called either by the president, the executive board, or not less than one-tenth of the members having voting rights.

SECTION 3. PLACE OF MEETING. The Executive Board may designate any place, either within or without the State of Illinois, as the place of meeting for any annual meeting or for any special meeting called by the Executive Board.

SECTION 4. NOTICE OF MEETINGS. Written or printed notice stating the place, day and hour of any meeting of members shall be delivered, either personally or by mail, to each member entitled to vote at such meeting, not less than five nor more than forty days before the date of such meeting, by or at the direction of the president, or the secretary-treasurer, or the officers or persons calling the meeting. In case of a special meeting or when required by statute or by these bylaws, the purpose for which the meeting is called shall be stated in the notice. If mailed, the notice of a meeting shall be deemed delivered when deposited in the United States mail addressed to the member at his address as it appears on the records of the Society, with postage thereon prepaid.

SECTION 5. QUORUM. Fifteen (15) Voting Members, or the designated representatives of Supporting Members, present at any meeting shall constitute a quorum. If a quorum is not present at any meeting of members, a majority of the members present may adjourn the meeting from time to time without further notice.

SECTION 6. ORDER OF BUSINESS. The order of business at meetings of the Society shall be arranged by the Executive Board, subject to additions or changes by the votes of a majority of the Voting Members and the designated representatives of Supporting Members present and voting.

SECTION 7. NOMINATIONS. The National Nominating Committee shall nominate at least one (1) eligible member for each elective office to be filled by vote of the Society as a whole at the next Annual Meeting. Each regional nominating committee shall nominate at least one (1) eligible member for the office of Regional Executive Board member for that Region as defined in Article IV, Section 2 of these bylaws, and shall report its nominees to the National Nominating Committee not later than January 15. The list of nominees for all elective offices shall be sent, by the National Nominating Committee, to the secretary-treasurer not later than February 1, and any vacancies in the list of nominees shall be filled in by the Executive Board before the ballot is sent to the Voting Members. Written consent shall be obtained from each nominee before the nominee's name is placed on the ballot.

SECTION 8. NOMINATING COMMITTEES. At each Annual Meeting, the presiding officer shall appoint (1) a National Nominating Committee consisting of six (6) Voting Members, who are not officers, and (2) a Regional Nominating Committee consisting of five (5) Voting Members, who are not members of the Executive Board, from each region for which a Regional Board Member is to be elected at the succeeding annual meeting.

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SECTION 9. VOTING. Voting shall not be restricted to the names presented by the Nominating Committees. Any fifty (50) Voting Members or designated representative of Supporting Members may file with the secretary-treasurer not later than January 15 the name of a candidate for any elective office for which they are entitled to vote, and the name of such candidate shall be placed on the ballot. Furthermore, any Voting Member may insert on the ballot the name of an eligible nominee of his own choice for any elective office for which he is entitled to vote.

SECTION 10. BALLOTS. The voting membership in each Region shall elect its Executive Board member, and the ballot shall clearly indicate the nominees for whom the members in the respective Regions are entitled to vote. The ballot must contain the names of all nominees for each office, arranged alphabetically and followed by a line on which the voter may write the name of an eligible nominee of his own choice. The ballot, with envelopes for secret voting, shall be placed in the mails to each Member entitled to vote not earlier than forty-five (45) days before the Annual Meeting and not later than twenty (20) days before the Annual Meeting.

SECTION 11. SEALED BALLOTS. Ballots shall be sealed and sent or delivered to the secretary-treasurer before the polls close prior to which time a voter may withdraw or replace his ballot. The envelope shall be signed by the voter who shall also type or letter thereon his name and his address as listed on the Society records.

SECTION 12. POLLS. The polls shall be closed at noon of the first day of the Annual Meeting, and the ballots shall be counted by five (5) Members of any grade appointed as tellers by the presiding officer at the Annual Meeting.

SECTION 13. ELECTION. The persons who receive the highest number of votes for the offices for which they were candidates shall be declared elected, providing that no one person may be elected to more than one office. In the event of a tie between candidates for the same office, announcement of the fact shall be made to the assembly immediately, and the Voting Members present at the closing session of the Annual Meeting shall elect the officer from the candidates so tied. The presiding officer shall announce to the Meeting the names of the officers so elected.

ARTICLE VII

Committees

SECTION 1. COMMITTEES OF THE EXECUTIVE BOARD. The Executive Board, by resolution adopted by a majority of the directors in office, may designate one or more committees, each of which shall consist of two or more directors, which committees, to the extent provided in said resolution, shall have and exercise the authority of the Executive Board in the management of the Society; but the designation of such committees and the delegation thereto of authority shall not operate to relieve the Executive Board, or any individual director, of any responsibility imposed upon it or him by law.

SECTION 2. OTHER COMMITTEES. Other committees not having and exercising the authority of the Executive Board in the management of the Society may be designated by a resolution adopted by a majority of the directors present at a meeting at which a quorum is present. Except as otherwise provided in such resolution, members of each such committee shall be members of the Society, and the Executive Board of the Society shall appoint the members thereof. Any member thereof may be removed by the person or persons authorized to appoint such member whenever in their judgment the best interests of the Society shall be served by such removal.

SECTION 3. TERM OF OFFICE. Each member of a committee shall continue as such until the next annual meeting of the members of the Society and until his successor is appointed, unless the committee shall be sooner terminated, or unless such member be removed from such committee, or unless such member shall cease to qualify as a member thereof.

SECTION 4. CHAIRMAN. One member of each committee shall be named chairman by the president of the Society. No chairman shall serve continuously for a term in excess of three (3) years.

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SECTION 5. VACANCIES. Vacancies in the membership of any committee may be filled by appointments made in the same manner as provided in the case of the original appointments.

SECTION 6. QUORUM. Unless otherwise provided in the resolution of the Executive Board designating a committee, a majority of the whole committee shall constitute a quorum and the act of a majority of the members present at a meeting at which a quorum is present shall be the act of the committee.

SECTION 7. RULES. Each committee may adopt rules for its own government not inconsistent with these bylaws or with rules adopted by the Executive Board.

ARTICLE VIII

Society Sections

SECTION 1. SECTIONS. Sections of the Society may be authorized by the Executive Board upon written petition of ten (10) or more Voting Members residing in a geographic area small enough to justify the belief that an effective local organization may be established. Section members shall be members of the Society. A Section must hold at least one meeting each year in order to retain its authorization.

SECTION 2. SECTION OFFICERS. Each Section shall have at least a chairman and a secretary as officers who shall keep the Executive Board informed of Section activities. The Section secretary shall transmit one copy of each paper delivered at Section meetings to the Executive Board for consideration of its suitability for publication by the Society. Submission of papers to the Executive Board does not preclude their publication elsewhere, either prior to or subsequent to the Section meetings at which they are presented.

SECTION 3. SECTION BYLAWS. Any Section may, subject to the approval of the Executive Board, adopt for its own government such bylaws as may be necessary, provided that no part of these bylaws shall conflict with the Articles of Association, Bylaws, or the policies of the Society.

SECTION 4. SECTION DUES. Sections may assess nominal dues in addition to the Society dues; and, if a Section desires, the secretary-treasurer of the Society will collect Section dues at the same time that Society dues are payable, such Section dues to be forwarded to the Section.

SECTION 5. SECTION MEMBERSHIP. Every member of the Society in good standing is automatically entitled to membership in that Section in which he establishes his domicile, but such affiliation is not mandatory. The domicile of a member shall be his home or residence, unless his place of business and his professional affiliations lie within the territory of another Section, in which event he may, by declaration, establish his domicile with said other Section for the purpose of Section membership. The domicile of a member, as so indicated, shall determine the Region in which he is entitled to cast his vote for a Regional Executive Board Member.

SECTION 6. SECTION TERMINATION. The Executive Board shall have the right at any time to revoke the authorization of any Section and to terminate its existence. A Section whose authorization has been revoked by the Executive Board shall have the right to appeal its case to the Society.

ARTICLE IX

Contracts, Checks, Deposits and Funds

SECTION 1. CONTRACTS. The Executive Board may authorize any officer or officers, agent or agents of the Society, in addition to the officers so authorized by these bylaws, to enter into any contract or execute and deliver any instrument in the name of and on behalf of the Society and such authority may be general or confined to specific instances.

SECTION 2. CHECKS, DRAFTS, ETC. All checks, drafts or other orders for the payment of money, notes or other evidences of indebtedness issued in the name of the Society, shall be signed by such officer or officers, agent or agents of the Society and in such manner as shall from time to time be determined by resolution of the Executive Board. In the absence

Research is the foundation of sound and economical manufacturing . . .

Research in the wood products industry has developed greater uses for greater utility and payrolls.

Research has made progressive lumber manufacturers leaders in the conversion of wood wastes into economical consumer products. Research will continue to conserve and protect a great natural resource—the forests.

Research has long been an integral part of the planning and operation of The Long-Bell Lumber Company, and research is destined to play an important part in the future of Long-Bell.

Since 1875

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KANSAS CITY, MO. LONGVIEW, WASH.

of such determination by the Executive Board, such instruments shall be signed by the treasurer or an assistant treasurer and countersigned by the president or a vice-president of the Society.

SECTION 3. DEPOSITS. All funds of the Society shall be deposited from time to time to the credit of the Society in such banks, trust companies or other depositaries as the Executive Board may select.

SECTION 4. GIFTS. The Executive Board may accept on behalf of the Society any contribution, gift, bequest or devise for the general purposes or for any special purpose of the Society.

ARTICLE X

Certificates of Membership

SECTION 1. CERTIFICATES OF MEMBERSHIP. The Executive Board may provide for the issuance of certificates evidencing membership in the Society which shall be in such form as may be determined by the Board. Such certificates shall be signed by the president or a vice-president and by the secretary-treasurer or an assistant secretary-treasurer and shall be sealed with the seal of the Society. All certificates evidencing membership of any class shall be consecutively numbered. The name and address of each member and the date of issuance of the certificate shall be entered on the records of the Society. If any certificate shall become lost, mutilated or destroyed a new certificate may be issued therefor upon such terms and conditions as the Executive Board may determine.

SECTION 2. ISSUANCE OF CERTIFICATES. When a member has been elected to membership and has paid any initiation fee and dues that may then be required, a certificate of membership shall be issued in his name and delivered to him by the secretary-treasurer, if the Executive Board shall have provided for the issuance of certificates of membership under the provisions of Section 1 of this Article.

ARTICLE XI

Books and Records

The Society shall keep correct and complete books and records of account and shall also keep minutes of the proceedings of its members, Executive Board and committees having any of the authority of the Executive Board, and shall keep at the registered or principal office a record giving the names and addresses of the members entitled to vote. All books and records of the Society may be inspected by any member, or his agent or attorney for any proper purpose at any reasonable time.

ARTICLE XII

Fiscal Year

The fiscal year of the Society shall begin on the first day of April in each year and end on the last day of March in the following year.

ARTICLE XIII

Purposes

The purposes of the corporation are stated in the ARTICLES OF ASSOCIATION.

The corporation, known as the Society, also has such powers as are now or may hereafter be granted by the General Not For Profit Corporation Act of the State of Illinois.

ARTICLE XIV

Offices

The Society shall have and continuously maintain in the State of Illinois a registered office and a registered agent whose office is identical with such registered office, and may have other offices within or without the State of Illinois as the Executive Board may from time to time determine. The address of the Registered Office is Room 2034, 332 South Michigan Avenue, Chicago 4, Illinois, and address of the Society headquarters is Box 2010, University Station, Madison 5, Wisconsin.

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ARTICLE XV

Seal

The Executive Board shall provide a corporate seal which shall be in the form of a circle and shall have inscribed thereon the name of the Society and the words "Corporate Seal, Illinois."

ARTICLE XVI

Waiver of Notice

Whenever any notice whatever is required to be given under the provisions of the General Not For Profit Corporation Act of Illinois or under the provisions of the articles of incorporation or the bylaws of the Society, a waiver thereof in writing signed by the person or persons entitled to such notice, whether before or after the time stated therein, shall be deemed equivalent to the giving of such notice.

ARTICLE XVII

Amendments to Bylaws

SECTION 1. ALTERING BYLAWS. These bylaws may be altered, amended, or repealed or new bylaws may be adopted by a majority of the Executive Board present at any regular meeting or at any special meeting, provided that at least ten days' written notice is given of intention to alter, amend or repeal or to adopt new bylaws at such meeting.

SECTION 2. PROPOSED AMENDMENTS. Proposed amendments to these bylaws, must be offered in writing, signed by at least five (5) Voting Members, and forwarded to the secretary-treasurer not less than sixty (60) days prior to the Annual Meeting. They shall be published with the notices for the meeting.

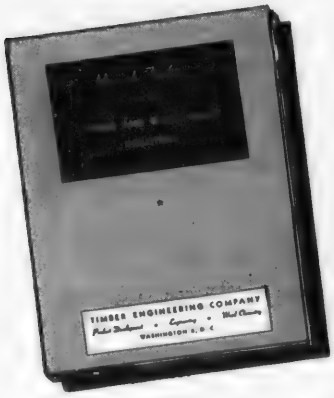
SECTION 3. BALLOT ON AMENDMENTS. Proposed amendments shall be in order for discussion at the Annual Meeting, and may be amended or approved if two-thirds of the votes of the Voting Members present and voting are affirmative. Such amendments shall then be submitted by letter ballot to the entire Voting Membership and shall be adopted if approved by a majority of the votes cast.

ARTICLE XVIII

Parliamentary law

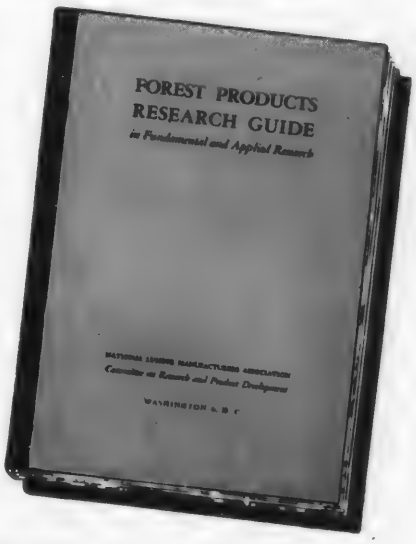
The latest edition of Robert's Rules of Order shall be followed in all meetings of the Society on points of procedure that are not specifically covered by these bylaws.

FOREST PRODUCTS *Research*



To meet the needs of small and large companies and associations for wood product development and wood chemistry research, the laboratories of the Timber Engineering Company have been established. Staffed with outstanding technologists in wood chemistry, gluing, kiln drying and wood uses the company will submit, without obligation on your part, proposals and estimates on your wood research problems. Write for free copy of our booklet "Research Facilities for the Lumber and Wood Using Industries".

The research specialists will want copy of the Third Edition of "Forest Products Research Guide" prepared and published by the Committee on Products and Research of the National Lumber Manufacturers Association. The new edition will be off the press about April 1. "Forest Products Research Guide" is the only publication of its kind. It lists all known U. S. organizations doing wood research and outlines the type of research being carried on. Place your order now with the National Lumber Manufacturers Association for the Third Edition. Price $5.00, postage paid.



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STYLE STANDARDS FOR FOREST PRODUCTS RESEARCH SOCIETY PAPERS 1947-1948

The Forest Products Research Society was founded as an organization to cover the fields of research, development, production, and utilization of forest products. The Society has as its objectives the following: facilitating the publication and interchange of information, encouraging cooperation, providing test methods and procedures, abstracting results, and, in general, encouraging and promoting the efficient utilization of wood and other forest products.

The Society solicits and encourages the preparation of papers by members and nonmembers for presentation and discussion at meetings and for publication. To qualify for Society sponsorship, papers must not only present suitable subject matter but must be well written and should conform to recognized style standards. The purpose of this style manual is to aid authors in meeting these requirements and to acquaint them with rules of the Society relating to the preparation and submission of manuscripts and accompanying illustrations. It is hoped that the necessity for conformance to certain rules or standards is recognized by everyone and that this Style Standard will serve as a guide and encourage the preparation and presentation of papers. Suggestions for the presentation of papers before meetings of the Society are included.

For those members of the Society well versed in the principles of good technical writing and presentation of papers, this style standard will contain little that is new because it follows rather closely similar standards of other societies. But, for those who are less experienced in writing and presentation of papers, it is hoped that this style manual will serve as a guide and contain helpful suggestions.

General

It is well to remember that the chief purpose of a paper is to convey information to others, many of whom are less familiar with the general subject than the author. This usually is accomplished most effectively through use of simple terms and expressions, by conciseness, and by omission of highly technical terms and phraseology except where the nature of the subject matter makes such terms unavoidable.

Papers should be kept as short as possible and as a general rule the text material should not exceed 4,000 words or about 14 double-spaced typewritten pages. Long quotations should be avoided by referring to source material. Illustrations and tables are desirable but they should be reduced to the minimum necessary to present and illustrate the results properly.

The desired order of the contents of papers is: (a) TITLE (b) Authors' name, business connection, and mailing address (c) Abstract (d) Body of paper (e) Appendixes (f) Bibliography (g) Tables (h) Captions for illustrations and (i) Illustrations, including graphs, charts, diagrams, sketches, and line drawings.

Copies of Manuscript

Two copies, an original and first carbon, are required for each paper or report submitted to the Society. Text matter must be typewritten, double spaced, on white paper; blue prints and "ditto" material are not satisfactory. Photographs or drawings should also be in duplicate, clearly identified. Photostats or copies may be used for the first carbon but not in the original.

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WILMINGTON 99, DELAWARE

Title and Author

Titles of papers should be definite in meaning and as short as possible. The author's name, title, affiliation, with city and state (territory or province) should appear immediately following the title, for example:

STRENGTH TESTS FOR DOUGLAS FIR

John J. Doe
Technical Director,
Rae Lumber Co.
Rae, California

Abstract

A short abstract (50 to 100 words) should be included on the first page immediately preceding the introductory paragraph and following the author's name and affiliation. The purpose of the abstract is to give the reader an indication of the paper's contents and it should be prepared with this purpose in mind.

Page Numbers

Number each page in the manuscript consecutively, including table and illustration pages, and appendix. Start the numbering with the first page of text (do not number the foreword or table of contents pages, or frontispiece illustrations). Put the number at the bottom of the page. If you wish to insert a page in a manuscript, give it the number of the preceding page, followed by an alphabetical letter, as follows: —1A—.

Tables

In general, long or detailed tables are not satisfactory to the reader or the printer. Usually, the summary or average figures are sufficient; too much tabular material may preclude printing by the Society. Tables should be numbered consecutively and should be referred to in the text as Table 1, 2, 3, etc. Tables of not more than six lines may be included in the text, but larger tables should be typed on separate sheets.

Graphs and Drawings

One or two clear graphs are often more usable to the reader than many tables. Cross section paper with faint lines or more than ten spaces to the inch will not provide a usable reproduction (see remarks on photographs and drawings).

Graphs, line drawings and sketches should be drawn with black ink on heavy white paper or tracing cloth. Blue prints and photostatic prints are not suitable.

Drawings for reproduction must be of good draftsmanship and of a size and weight of line so that they can be reduced to the width of a column or a page. Preferably, the drawings should be exactly four times as large as the size required for the finished cut, and the capital letters on the inked drawing should be 0.25 in. high. Use black india ink, medium weight lines and uniform letters; fine lines, figures close to lines, and pencil shading will not reproduce.

Photographs

Photographs must be clear, detailed prints (preferably glossy) in a size of 5 by 7 in. or 8 by 10 in. Blurred, dark, or half-tone copies cannot be used. The presentation may be improved by one or two good pictures, but they should be held to an absolute minimum and definitely related to important features of the text.

Photographs should not be mounted or pasted in the manuscript. Paper clips will mar photographs and should not be used unless photographs have wide margins. Fasten the photograph to sheets by making slits in the page or by means of corner markings.

The main title of the photograph, drawing or graph will be set in type by the printer and should be firmly attached to the illustration. The proper figure number and the author's name marked lightly on the back and margin of prints often is helpful in identifying material. However, such identification should be made with a pen and blue ink. Also, ball-point pens should not be used because they may mar the photograph.

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Lettering

There are several important points that must be observed in connection with lettering on graphs, drawings and other illustrative material. With few exceptions lettering done with lettering guides is superior to freehand lettering and should be used wherever possible. Since most illustrative material is greatly reduced in size on publication, letters must be of sufficient size and lines heavy enough to reproduce.

Headings and Numbering

Headings and subheadings should appear throughout the text to divide the subject matter into logical parts and to emphasize the major elements and considerations.

Tables, other than brief tabulations appearing as part of the text, should be numbered consecutively throughout the paper, including appendixes, if any, using arabic numerals.

All illustrations, including graphs, charts, diagrams, sketches, line drawings, and photographs, should also be numbered consecutively throughout the paper, including appendixes, if any, using arabic numerals. All such illustrations are properly referred to as "figures."

Footnotes

Footnotes are used to make minor explanations of material in the text. They are also used for literature references (see Literature Citations).

Footnote references are numbered consecutively from beginning to end of the manuscript. (Tables are footnoted separately). Two footnote references occurring in the same place are separated by a space ([3] [4]).

The footnote itself should preferably be typed immediately following the line in which the footnote reference is placed and should always be kept on the same page with its reference.

Numerals

Do not begin a sentence with numerals.

Whole numbers through ten; spell out (unless used in sequence with larger numerals).

Fractions and numbers greater than ten; use numerals.

Identification numbers; as Fig. 1, page 6, etc. use numerals.

Units of measure; as 6 ft., 2 gal., etc. use numerals.

Ciphers are required before the decimal point in quantities that are less than 1.0; 0.55 lb. retention. In case readings are carried out to several places (example: 1.100) the ciphers should be included.

Express percentages and precise figures as decimals; 3.5 percent, not 3½ percent.

Numbers following numbers, as forty 4-in. timbers; spell first, numerals for second.

Series of numbers of more than four figures in the text, point off; as 1,234,567, but space in tabular matter 1 234 567.

Capitals

Use capitals sparingly; it is not good practice to use them for emphasis in technical writing. Capitalize principal words in headings and titles. Capitals are used for: Vol. 26, Table III, test No. 1, specimen A, the North region, Committee on Wood Preservation, Lake Erie, President John Doe, the North and South Railroad, or Douglas fir. Use lower case for: north or northern (merely denoting direction); the committee recommends; John Doe, president; portland cement; diesel engine, southern pine; and western hemlock.

Compound Words

The only simple rule that can be given regarding the use of hyphenated words is: two or more words used as a unit modifier are hyphenated. Examples:

wood-using industries	10-year growth
old-age trees	½-acre plots
two 16-foot sawlogs	three-fourths inch
air-seasoned lumber	two 16-foot sawlogs

Hyphens are used not only to join words, but to keep the components separated for ease of reading (A-frame, man-hours) and to prevent misunderstanding (co-op, re-treat).

Society or Association Names

Refer to the Forest Products Research Society as the Society or the FPRS. When mentioning other groups spell out the name in full when the first reference is made, then use the initials, as follows: ACS, ASTM, ASME, SAF, etc.

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Abbreviations

Do not abbreviate terms that are infrequently used. Abbreviate common units of measure only when used with numerals denoting a definite quantity (except in tabular material), for example: 40 bd. ft. were selected; and several board feet of lumber were added.

Plural expressions should be abbreviated in the singular, thus: 2 in., not 2 ins., nor two inches. Express dimensions as 2 by 4 in., not 2 in. x 4 in.

The use of chemical symbols, in general, should be kept to a minimum, except in tables and methods of analysis; however, common names when first used should be followed by the chemical formula to insure identification. Correct abbreviations for scientific and technical terms and for standard lumber terms are as follows:

SCIENTIFIC AND TECHNICAL TERMS

Absolute	abs.
Alternating current	a.c.
(as adjective)	a-c.
American wire gage	A.w.g.
Ampere	amp.
Ampere-hour	amp-hr.
Angstrom unit	A
Average	av.
Barrel	bbl.
Birmingham wire gage	B.w.g.
Brake horsepower	b.hp.
British thermal unit	Btu.
Brown and Sharpe (gage)	B.&S.
Bushel	bu.
Calorie	cal.
Centigrade	C.
Centigram	cg.
Centiliter	cl.
Centimeter	cm.
Cents	spell out
Chemically pure	c.p.
Circular mils	cir. mils
Cubic	cu.
Cubic centimeter (volume)	cu. cm.
Day	spell out
Decigram	dg.
Deciliter	dl.
Decimeter	dm.
Degree or degrees	deg.
Diameter	diam.
Direct current	d.c.
(as adjective)	d-c.
Electric horsepower	e. hp.
Electomotive force	emf.
Equation	Eq.
Fahrenheit	F.
Figure, Figures	Fig., Figs.
Foot or feet	ft.
Foot-pound	ft-lb.
Gallon or gallons	gal.
Gallons per minute	gpm.
Grain	spell out
Gram or grams	g.
Horsepower	hp.
Horsepower-hour	hp-hr.
Hour or hours	hr.
Hydrogen ion concentration	pH
Inch or inches	in.
Inch-pound	in-lb.
Indicated horsepower	i.hp.
Kilocycle	kc.
Kilogram	kg.
Kilogram-calorie	kg-cal.
Kilogram-meter	kg-m.
Kiloliter	kl.
Kilometer	km.
Kilovolt	kv.
Kilovolt-ampere	kva.
Kilovolt peak	kv.p.
Kilowatt	kw.
Kilowatt-hour	kw-hr.
Less than carload	l.c.l.
Linear	lin.
Liter	l.
Logarithm (common)	log
Magnetomotive force	mmf.
Maximum	max.
Meter	m.
Meter-kilogram	m-kg.
Microfarad	μf
Micro-microfarad	$\mu\mu$f
Micromicron	$\mu\mu$
Micron	μ
Mile	spell out
Miles per hour	mph.
Milliampere	ma.
Milligram	mg.
Millihenry	mh.
Milliliter	ml.
Millimeter	mm.
Millimicron	mμ
Millivolt	mv.
Minimum	min.
Minute or minutes	min.
Month	spell out
Number	No.
Ohm	spell out
Ounce	oz.
Parts per million	ppm.
Per	spell out
Percent	spell out
Per centum	per cent
Pint	pt.
Pound or pounds	lb.
Pound-foot	lb-ft.
Pound-inch	lb-in.
Pounds per square foot	lb. per sq.ft.
Pounds per square inch	psi.
Quart	qt.
Radius	rad.

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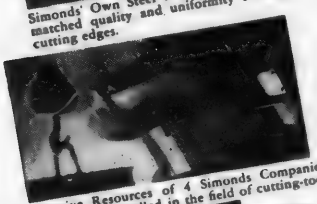
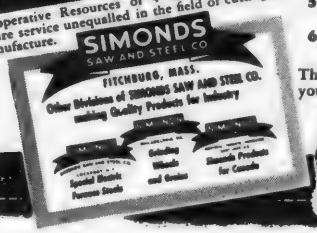


Co-operative Resources of 4 Simonds Companies assure service unequalled in the field of cutting-tool manufacture.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SCIENTIFIC AND TECHNICAL TERMS—Continued

Revolutions per minute	rpm.
Root mean square	rms.
Second or seconds	sec.
Specific gravity	sp.gr.
Square	sq.
Tensile strength	tens.str.
Ton	spell out
United States (gage)	U.S.
Volt	spell out
Volume, Volumes	Vol., Vols.
Watt	spell out
Watt-hour	w-hr.
Week or weeks	spell out
Yard or yards	yd.
Year or years	yr.

STANDARD LUMBER TERMS

Air-dried	AD
Board	bd.
Board foot	bd.ft.
Board (foot) measure	b.m.
Better	Btr.
Clear	Clr.
Center matched	CM
Common	Com.
Cubic foot	cu.ft.
Dressed and center matched	D&CM
Dressed and matched	D&M
Dressed two sides and matched	D2S&M
Dimension	Dim.
Edge grain	E.G.
End matched	EM
First and seconds (hardwood grades)	FAS
Flat grain	F.G.
Flooring	Flg.
Feet board measure	feet b.m.
Hardwood	hdwd.
Heart	Hrt.
Heartwood	Hrtwd.
Kiln-dried	KD
Knocked down	k.d.
Lumber	lbr.
Length	lgth.
Linear foot	lin.ft.
Log run	LR
Thousand	M.
Thousand (feet) board measure	M.b.m.
Merchantable	Merch.
Mill run	MR.
Thousand (feet) surface measure	M.s.m.
Plain, as plain sawed	Pln.
Quartered—referring to hardwoods	Qtd.
Random	rdm.
Random lengths	r.l.
Round	rnd.
Random widths	r.w.
Surfaced 1 side and 1 edge	S&E
Surfaced one edge	S1E.
Surfaced two edges	S2E.
Surfaced one side	S1S.
Surfaced two sides	S2S
Surfaced 2 sides and 1 edge	S2S1E
Surfaced four sides	S4S
Sapwood	Sap.
Select	Sel.
Softwood	Sftwd.
Sound	snd.
Square	sq.
Square edge and sound	Sq. E. & S.
Squares	sqrs.
Standard	Std.
Tongued and grooved	T&G
Timbers	Tbrs.
Thickness	4/4, 6/4, etc. = 1 inch, 1½ inches, etc.
Vertical grain	V. G.
Width	Wth.
Weight	wt.

The use of symbols such as % for percent, ° for degree, ′ for feet or minutes, ″ for inches or seconds, should only be used in complex tabular data. The symbol # should not be used for any purpose. The abbreviation ml. for milliliter to indicate a measure of capacity is preferable to cc.

Common Names

The common names of species of wood should be the ones in general use in the industry, and, to avoid the possibility of confusion, the scientific name should appear in italics after the common name the first time it is used in the paper.

Literature Citation

Reference to literature the author has consulted can be made in two ways: (1) as a list at the end of the manuscript; or (2) as footnotes. A list of Literature Cited should contain at least seven references. (If you have less than seven, use them as footnotes.).

EXAMPLES:

Books:

Sargent, Charles Sprague. 1905. Manual of the trees of North America. Ed. 2, 818 pp., illus. Boston and New York.

Periodicals:

Simmons, Fred C. 1945. Methods of loading lumber at the rear of small sawmills. Canada Lumberman 65 (23): 39–40, illus.

Bratton, Allen W. and R. H. Ferguson. 1945. Use of the spray gun in marking timber. Jour. Forestry 43: 113–117.

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» » » LAFAYETTE 8161 « « «

Generally the volume of the periodical and the pages are all you need to give (Jour. Forestry 43: 744–749 and not Jour. Forestry 43 (10): 744–749).

Type Literature Cited lists double-space. Arrange the list in alphabetical order, according to author, and give each publication a number.

Editing

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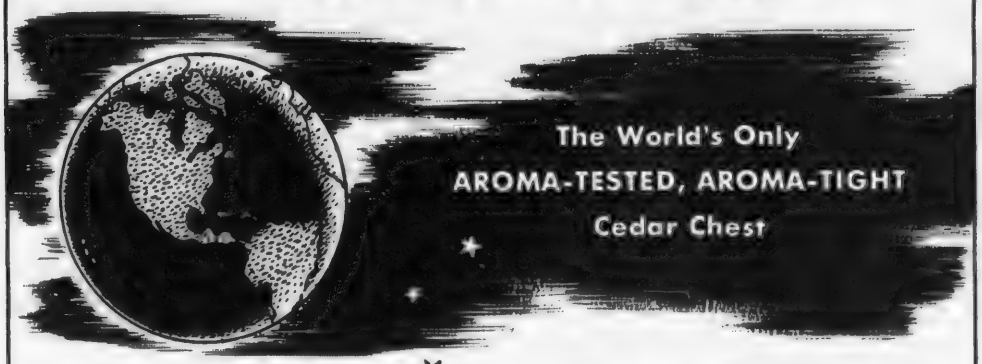

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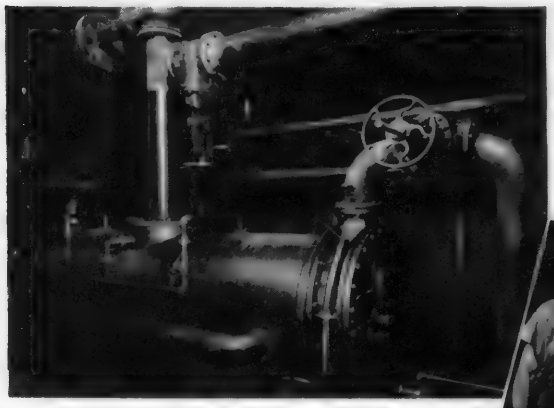
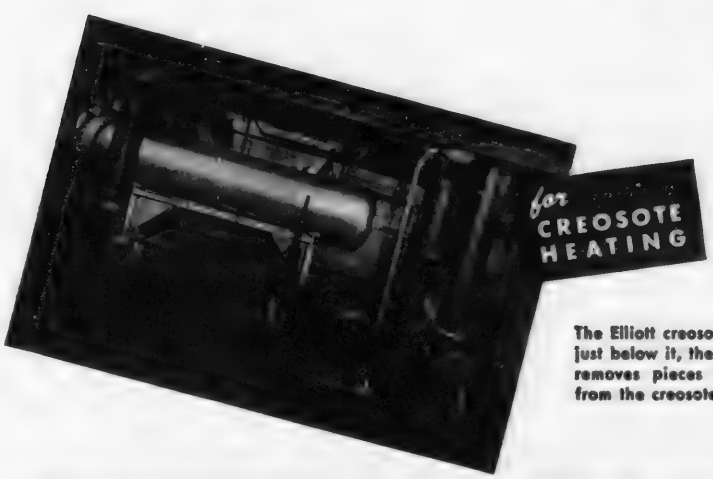


At left, Elliott surface condenser used in vacuum system. Just below, an Elliott twin-two-stage ejector arrangement before installation in a wood preserving plant. At bottom, a typical Elliott single-stage ejector.

MODERN EQUIPMENT *for* WOOD PROCESSING



The Elliott creosote heater in service. Note just below it, the Elliott twin strainer which removes pieces of bark and wood fibre from the creosote to be heated.

Q-1134

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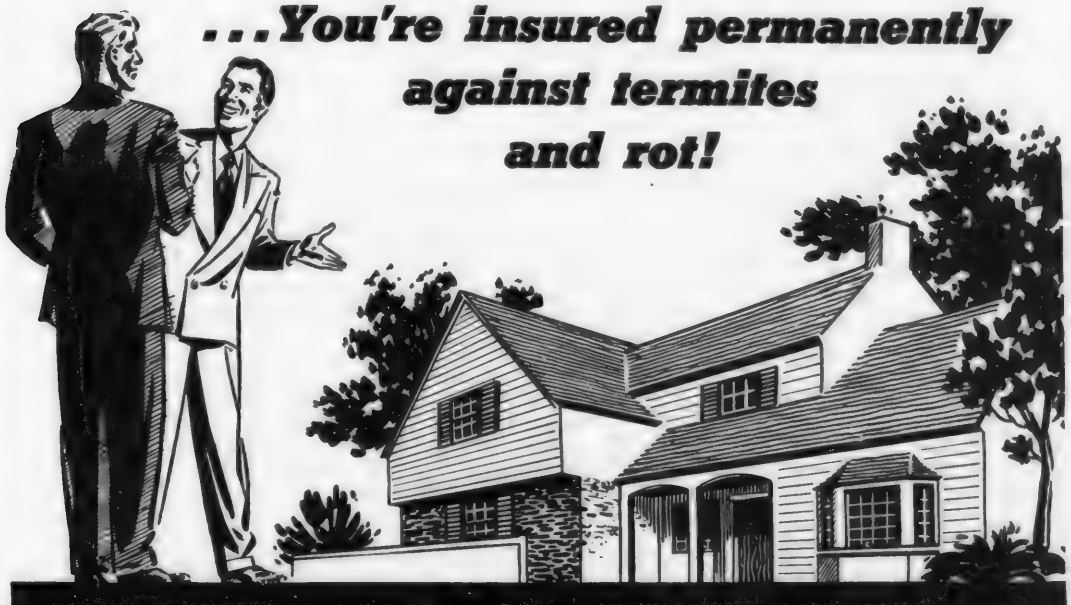

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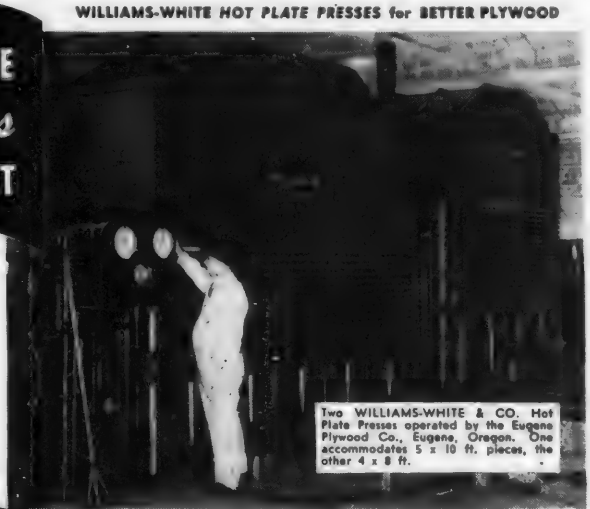

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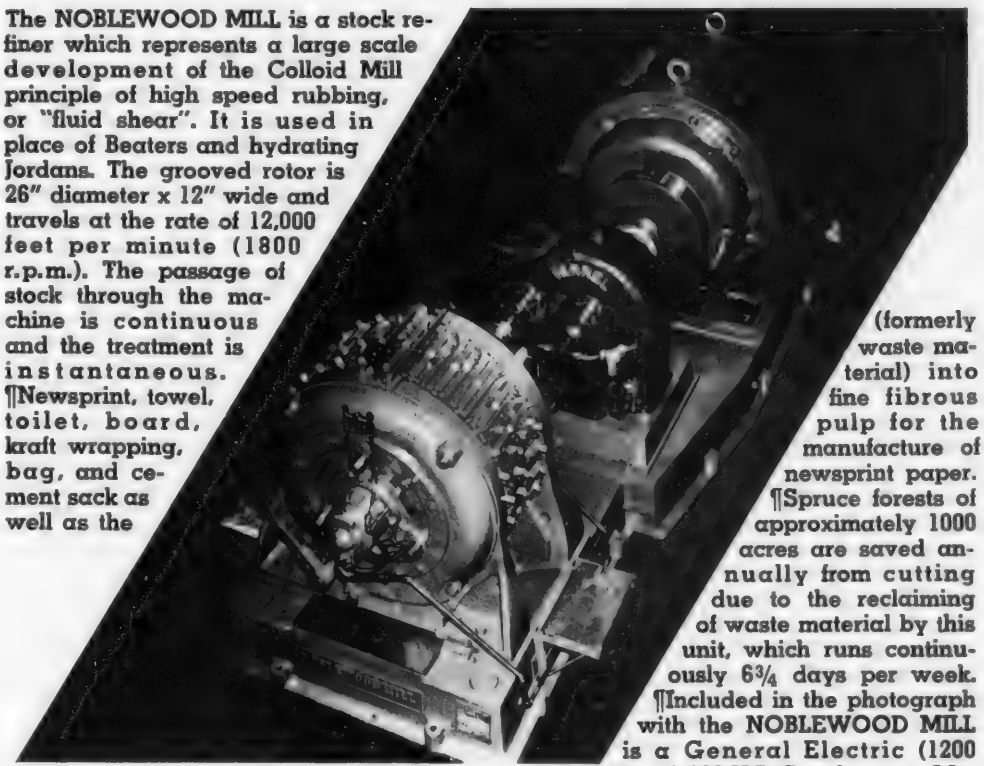

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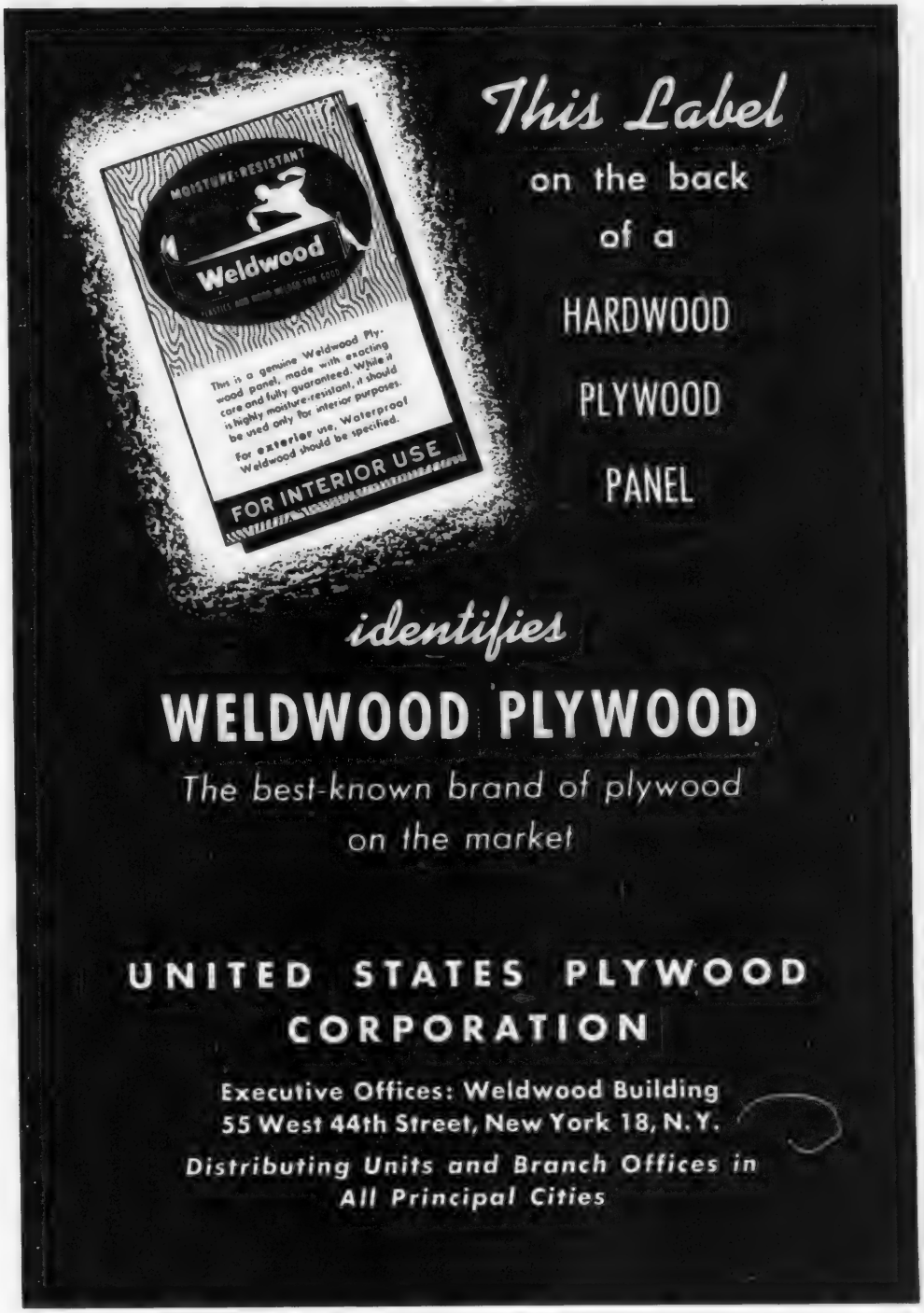
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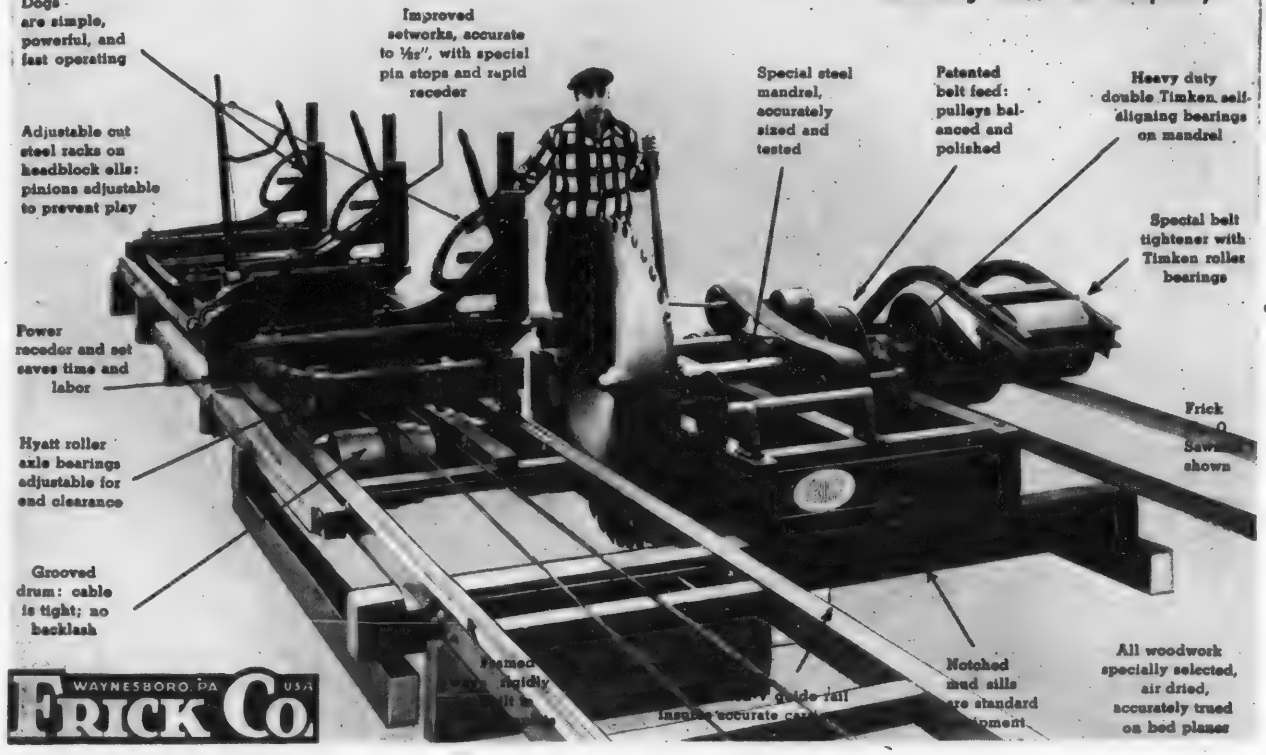
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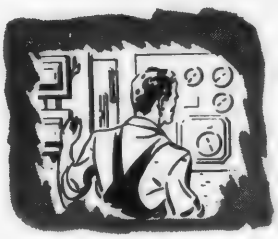

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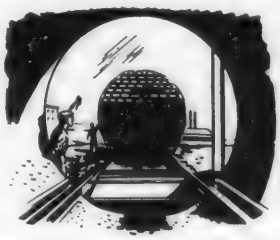

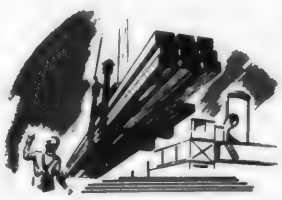

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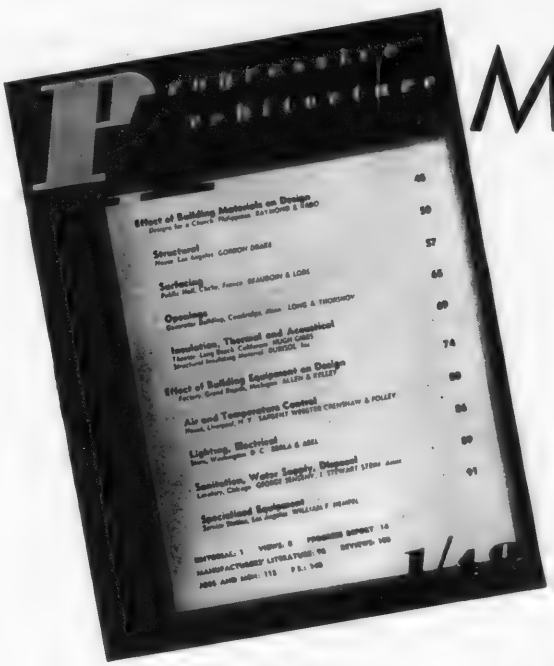

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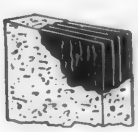

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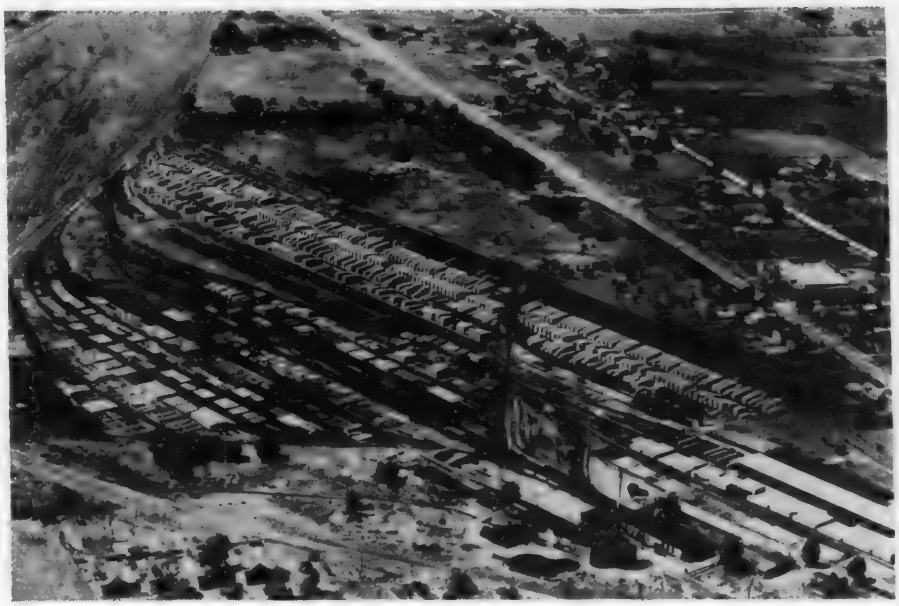

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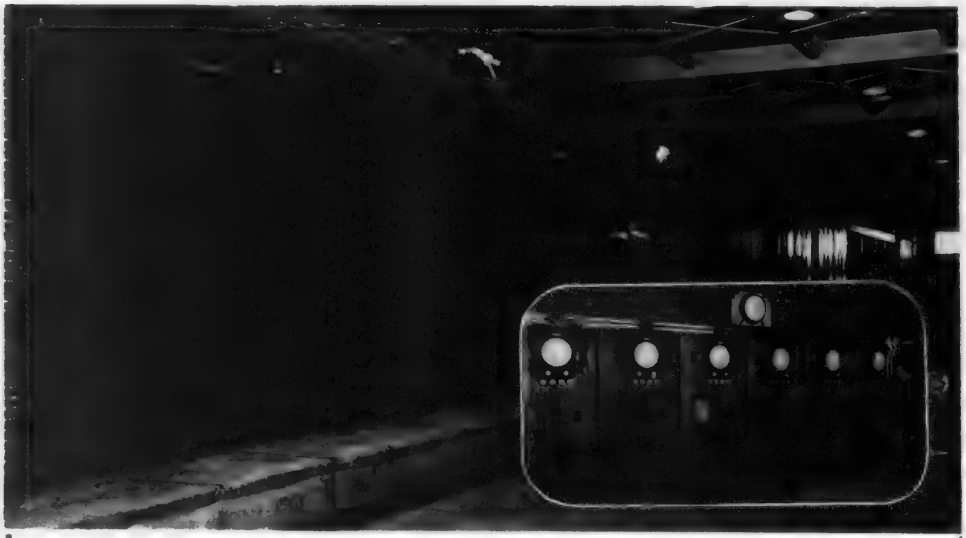

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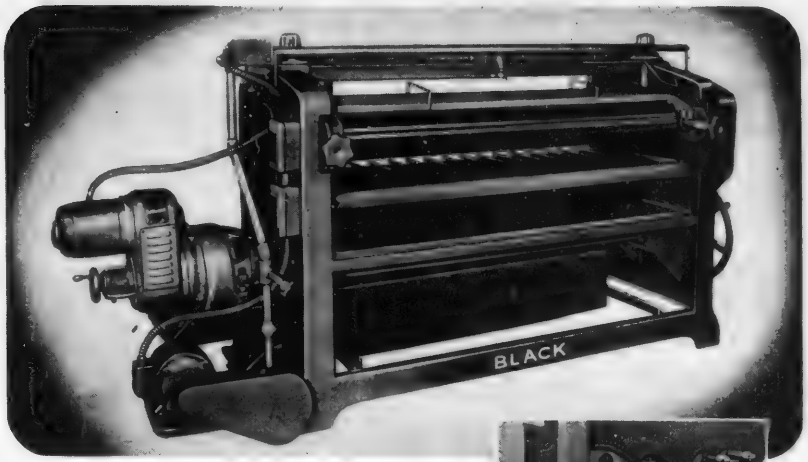

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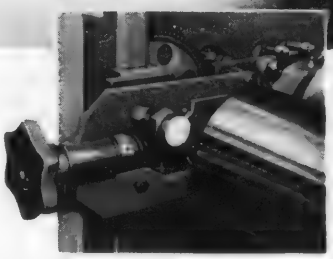

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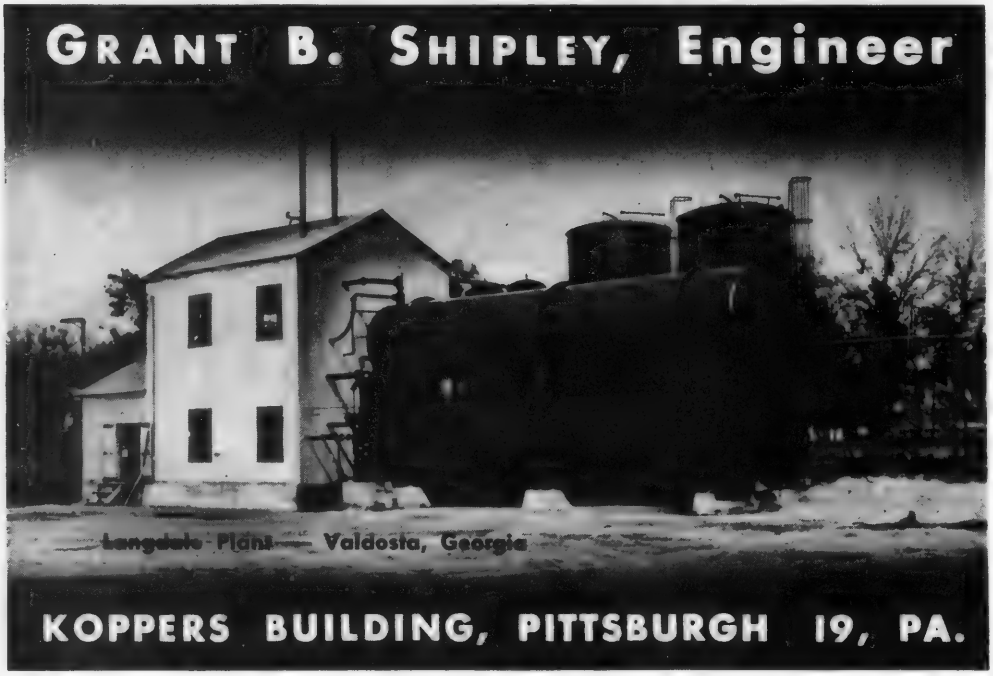

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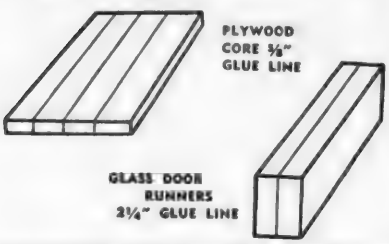

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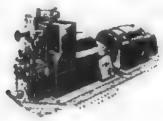

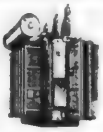
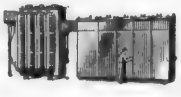
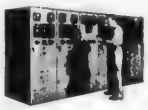

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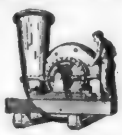
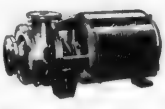

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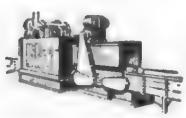
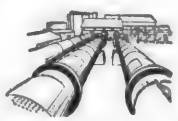

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BARKING EQUIPMENT — Allis-Chalmers' "Streambarker" hydraulic log barker removes bark from pulpwood sticks of 4 to 18 inches diameter and up to 8 feet long, by means of water under 650 to 800 lb pressure. Capacities range from 8 to 14 cords per hour, depending on condition of wood, season, etc. Allis-Chalmers builds, in its own shops, the complete Streambarker unit, including barker, pump, motors, controls and bark screen.

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"Another very fertile field for improvement lies in common, everyday cross ties. All of the railroads used untreated cross ties up to some 25 or 30 years ago, but now about all use creosoted ties, or ties treated in some other way, and we have increased the life of a wooden cross ties from some 7 to 8 years up to possibly 25, 30 or more years, merely by preserving the tie against decay. That was tremendous conservation as well as economy brought about by 'research and development'. But we are only part way. Little has been done to improve the physical characteristics of the wooden tie, which has a way of splitting, checking or being soft. Wood is a natural product and it has been assumed that nothing could be done to improve it; that when it dries out or 'seasons', it will split and check, and nothing could be done about it. That is far from the truth. In at least one place a process has been developed for drying out an oak tie in 7 or 8 hours as compared with the usual 15 months in the seasoning yard, and doing it with little or no damage to the wood. When the tie is dried out in a temperature of about 320° F. in about 8 hours, it becomes hot through and through, and then it may be impregnated with creosote to much better advantage. The whole process consumes about 12 to 15 hours. Some such method might be what we are looking for, but no one would say that is the only method.

"Inspection of ties in the track, after some years' use in the south country, leads us to believe that perhaps a third to a half of the tie failures have their origin in splitting and checking. If we can lick this problem, and can thus increase the life of a tie by even 4 or 5 years, it would mean 'conservation of resources' on a big scale—and our timber has been depleted rapidly. It would mean a sizeable reduction in expenses for any railroad . . ."*

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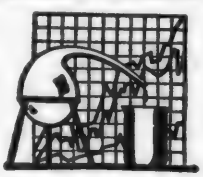

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